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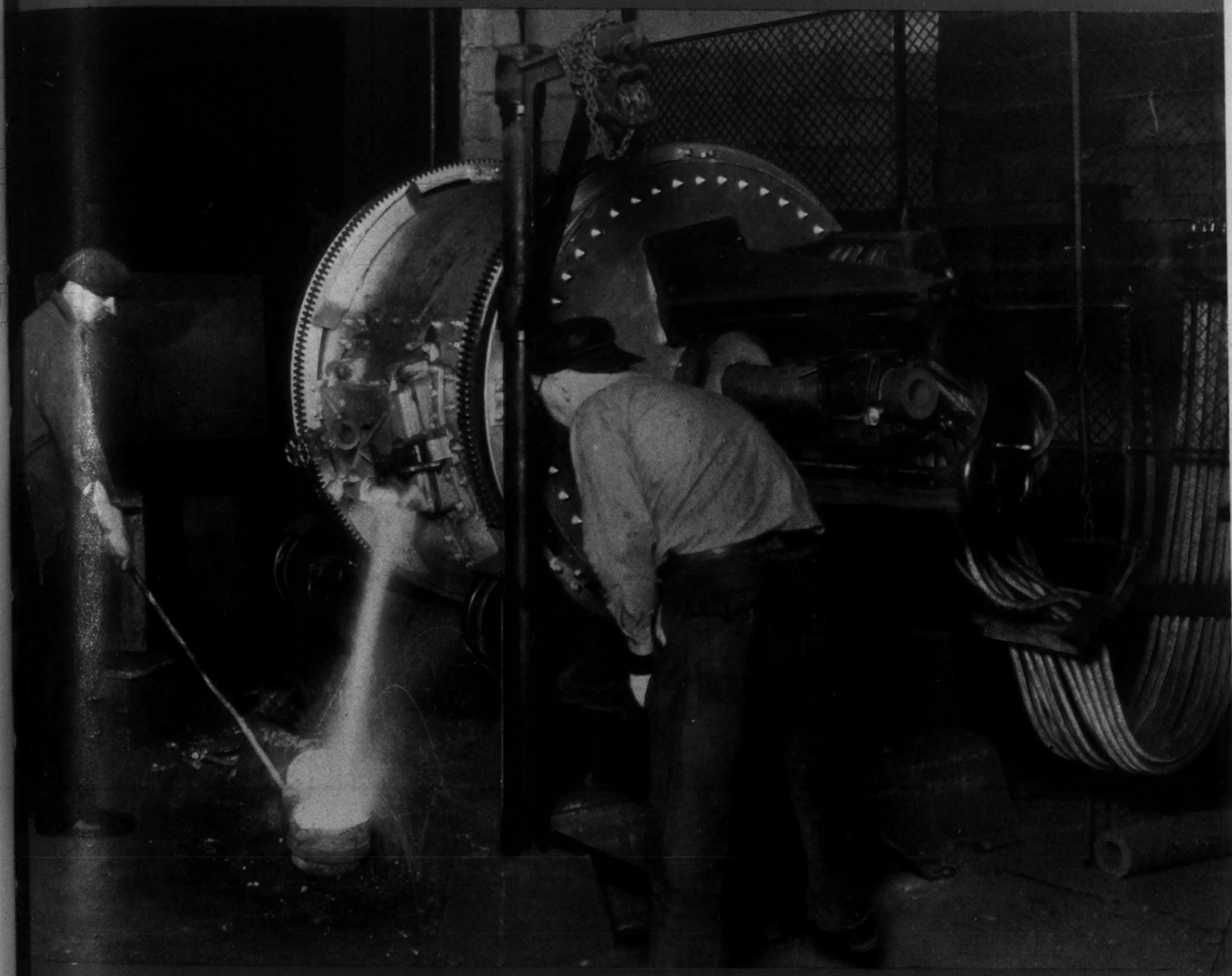
CURRENT METALLURGICAL ABSTRACTS



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VOLUME 4

MAY
1933

NUMBER 5

HIGHLIGHTS by H. W. GILLETT

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METALS & ALLOYS
RICHARD RIMBACH, Editor

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HIGHLIGHTS by H. W. GILLETT

Speaking of Aluminum, Thews (page MA 133 R1) gives analyses of over 100 trade named aluminum alloys, and a new book by Budgen (page MA 133 L1) discusses heat treatment of aluminum alloys.

How Many Steels Are There? If there are 100 aluminum alloys, how many steels are there? At least 166 in German practice, for Eichwald (page MA 135 L1) gives compositions and properties of that many, with special reference to automobile service.

Cast Iron. Yes—there are many varieties of cast iron, too. Brialmont (page MA 135 R2) gives data for 30 varieties tested in Belgium. Cast iron has different properties depending on the thickness of the casting and Ballay (page MA 135 R1) gives French data, Koch (page MA 135 L7) German data, Pearce (page MA 134 L6) English data and Gilligan and Curran (page MA 134 R1) American data on this. Judson (page MA 134 L5) cites an American iron, made in a peculiar way, that doesn't need risers even in heavy sections. Growth of cast iron is discussed by Ebling of Germany (page MA 135 L10) and d'Ardigny of France (page MA 135 R10). Baron of Belgium (page MA 134 L8) says that manganese sulphide inclusions in gray iron may injure machinability, when you wouldn't guess it from the hardness of the iron.

Alloy Steels? Of Course. Houdremont and co-workers (page MA 135 R3) tell about retention of temper in tungsten and vanadium steels. "Anon" *Canadian Chemistry & Metallurgy* (page MA 135 R7) discusses 18-8 but this has manganese instead of nickel, with some copper added. Copper helps that steel, and Wiessner (page MA 135 R8) tells us that in turn, molybdenum helps a copper steel. Seems as though we'd heard that before—page Toncan.

Speaking of the Rarer Metals. We have rhenium (Meggers) (page MA 132 L8), gallium (Kroll) (page MA 133 R3) and thallium (Centnerszwer) (page Ma 138 R10).

Is Pure Titanium Brittle? Most people would say it probably is, but Van Arkel (page MA 132 L4) has made pure ductile Ti and V. Sloman (page MA 132 L6) finds that beryllium isn't brittle either, unless it contains oxide.

Magnet Alloys. There's a fine new book on magnet alloys by Messkin and Kussmann (page MA 134 L1). Yes, they're Russian, but this book is in German, and the reviewer says it's easy reading.

Coatings Resistant to Corrosion and Wear and providing electrical insulation are made by anodic treatment in a chromic acid, oxalic acid bath—says Schmitt of Germany (page MA 146 R7) while Matthaes (page MA 133 R5) states that anodic oxidation improves resistance to corrosion fatigue.

Galvanized Iron. Watch out when using galvanized iron in contact with refined oil, says Frank (page MA 137 L1) as it corrodes badly in oil tankers carrying refined oil. However, the organic coatings proposed as substitutes also have drawbacks.

DO YOU want to know what metallurgical engineers are saying, the world over? Look in the Current Metallurgical Abstracts. Here are some of the points covered by authors whose articles are abstracted in this issue.

Inclusions in Wrought Iron say Hensel and Hengstenberg (page MA 135 L4) don't affect longitudinal properties very much. Transverse properties are another story, but even there the endurance limit wasn't affected as much as would have been expected. When they carburized the material it appeared that inclusions are far more damaging in hard than in soft metal. Lea (page MA 134 L10) deals with the same basic question but especially in respect to surface discontinuities.

Precious Metal Alloys Receive Attention. Shell (page MA 141 L1) deals with Au-Ni, Kleinert (page MA 142 R7) with Ag-Cu-Zn, and Ölander (page MA 143 L10) with Au-Cd.

Cutting Tool Developments. About the new developments in cutting tools arising from the tungsten carbide class of alloys with cobalt. You'll want to see what progress Vogel and Sundermann (page MA 140 R1) have made on fundamentals in respect to Fe-Co-C, Köster (page MA 140 R3) on Fe-Co-W and Fe-Co-Mo, and Agte, Becker and von Göler (page MA 143 L3) on W-Co.

Corrosion? Yes Indeed. This issue contains too many to allow picking out anything like all the important ones. Speller for the ASTM (page MA 137 L4) again remarks that solution in acid doesn't correlate with atmospheric service. Vernon (page MA 136 R7) tells how copper acquires its surface film, Wilson (page MA 138 L6) says it isn't the water in the automobile radiator that corrodes, it's the air in the water. The Pacific Coast Electrical Association (page MA 139 L6) says not to put copper in contact with lead in moist places. If you do, look out for attack. Ottenstein (page MA 136 R10) thinks copper electroplated with tin makes the best hot water tank. Kolke (page MA 138 L8) says you don't want phosphate coatings on steel to receive acid proof lacquers. On corrosion theories, Liebreich (page MA 139 L9) disagrees with Evans, and Akimow (page MA 136 R1) springs still another new theory of corrosion. Irrespective of theory, Britton, Hoar and Evans (page MA 138 R8) say that under 5 parts per million of H_2S greatly accelerate the corrosive effect of chloride solution on steel.

Scaling Losses. Scaling losses were determined by heating ingots in a pusher furnace. Schroeder (page MA 138 R1) discusses gas atmospheres that will reduce scaling, as determined in comprehensive studies. That's for a carbon steel in process of manufacture. For parts to resist scaling, von Schwarze (page MA 138 R6) studied chromium-aluminum steels up to 20% of each element. He likes the protective effect of the scale due to aluminum.

Heat Treatment. In heat-treatment by quenching or normalizing, go above A_3, says Whiteley (page MA 140 R9), else the mixed structure resulting will produce low impact values.

How Shall We Test a Galvanized or Tinned Coating? The Russians Isgarishev and Egorova (page MA 146 R2) approve of two methods but decry the copper sulphate test. Macnaughtan and co-workers (page MA 137 L2) say all you need to test for porosity in tin plate is just some hot water.

Notches. Greaves (page MA 144 L9) finds that notched bar impact tests agree with performance in service. Several other articles (page MA 144) discuss details of making impact tests. Standardization of methods is sought, but is slow in coming. Speaking of notches, especially in relation to fatigue, Frocht (page MA 145 L5) finds that if the notches are close enough together, their effect may cancel. Perhaps that's why cast iron is relatively insensitive to the notch effect. Armbruster (page MA 146 L1) suggests other ways to avoid the notch effect from holes, such as chamfering and work-hardening the edges. Solakian and Karelitz (page MA 144 L4) favor rounding off keyways, for the same purpose.

Unusual Testing Methods. Unusual testing methods were used in several studies reported. Frocht (page MA 145 L5) used moving pictures in study of photo-elasticity, while Koegel (page MA 143 L5) went still further, using X-ray, stereoscopic moving pictures. Pullin (page MA 143 L8) uses radium for radiography. Both Norton (page MA 142 R1) and Regeler (page MA 142 R2) use X-rays to detect hidden stresses in welds. Von Schwarz (page MA 140 L10) applies polarized light to the microscope for metallography, revealing new facts. That phenomenon known as damping, the internal absorption of energy, in which metals and alloys vary widely and which must have a relation to service behavior when we know more about it, is studied by Götzelt (page MA 144 R8).

New Kinks in Testing Methods. New kinks in other testing methods that are more or less known but which are not entirely standardized are brought out by Larard (page MA 145 L4) who refines the torsion test, Jurczyk (page MA 146 L6) who studies bend testing, a German article (page MA 146 L3) which discusses tensile impact, Rosenberg and Herschmann (page MA 144 L7) who summarize the wear testing situation, and Buxbaum (page MA 145 L1) who suggests determining hardness by a file which itself varies in hardness along its length.

How About Theory? Yes—Avetissian (page MA 131 R1) gives a theoretical discussion of thermodynamics of steel melting and copper refining in Russian and Kikuchi (page MA 132 L5) discusses the Wiedemann Franz law in respect to magnesium alloys in Japanese. Mathematical relations correlating the electrical conductivity of very thin metallic layers are given by Hamburger (page MA 132 L3) in German. Don't look for much detail in the abstracts, they aren't that kind of articles.

Carbon Steel or Alloy Steel? Here's something we can all read, for it's in English, and can all understand—a discussion whether carbon steel is used to best advantage by Thomas (page MA 134 R2). In other words carbon steel plus enough care often equals alloy steel. Which costs more, the care or the alloy? Well, that depends!

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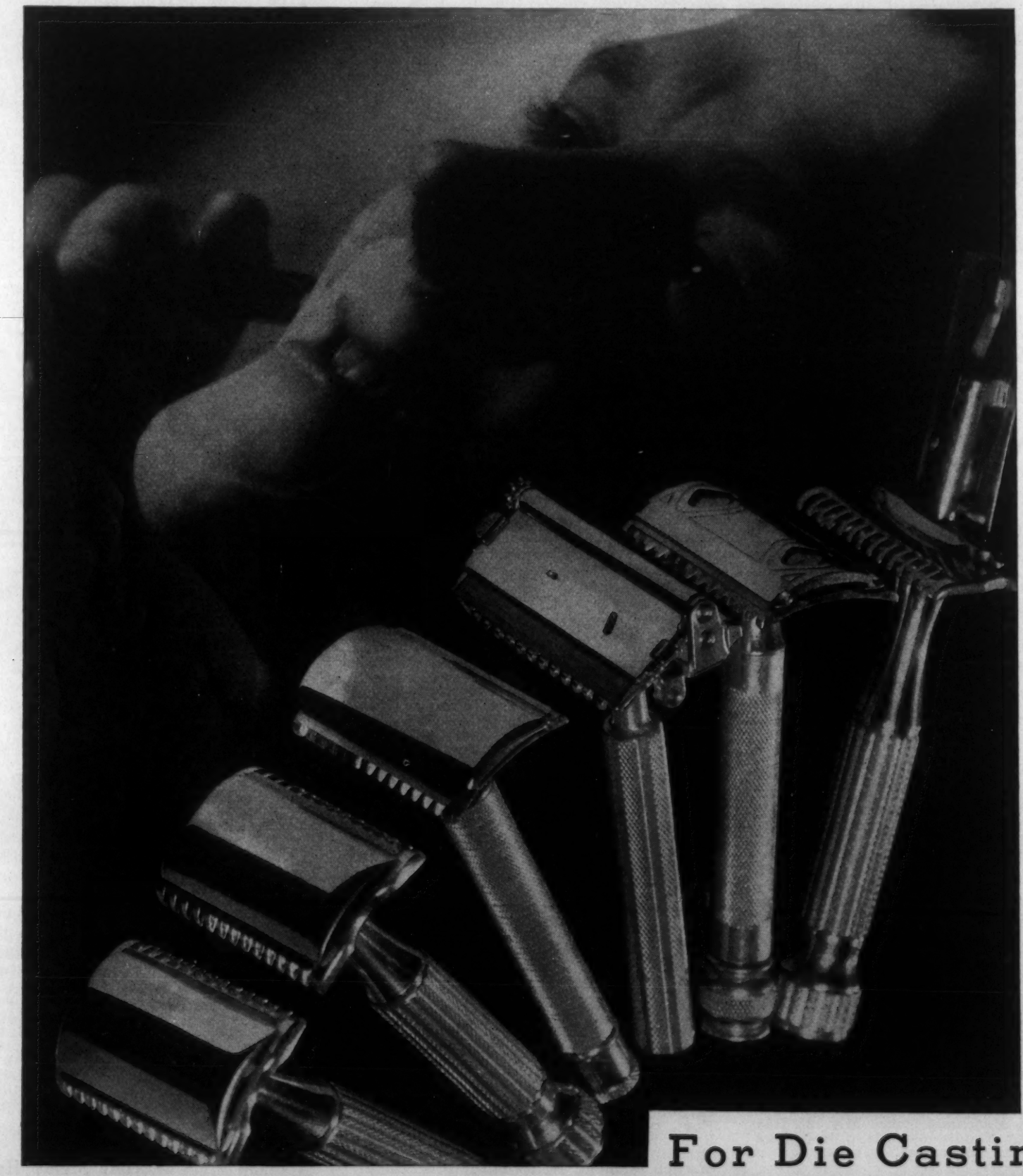

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EDITORIAL COMMENT

Traces

WE ARE accustomed to ignore the presence of a few hundredths of a percent of foreign element or impurity in a metal when this is commonly associated with it, and does not have a striking harmful effect. Copper and arsenic in steel, cobalt in nickel, oxygen in copper, iron and silicon in aluminum, cadmium in zinc, and so on, are, or were, accepted as pretty much inevitable, and hence, rather ignored. However, oxygen-free copper, Hoopes' aluminum, and electrolytic zinc have recently become available in such quantities, and so much work has been done with them, that the difference between a really pure metal and one slightly contaminated or alloyed is much better appreciated. Some of the alloying effects of "impurities" are beneficial. Had commercial aluminum been free from silicon, Wilm would not have stumbled on the heat-treatment of duralumin when he did. The very tiny amount of silver in Lake copper raises the annealing temperature notably, and thus specially fits it for use where it needs to withstand soldering temperatures without softening, as in automobile radiators.

The earlier metallurgy often surveyed the effect of one alloying element upon another in a preliminary way, by adding it in steps of 5 or 10%. Now that the precipitation hardening effect is known, it is recognized that few systems can be left without studying the effect of a change of a few tenths of a percent of the alloying element when the solubility curves indicate the possibility of changing solubility with temperature, and thus of precipitation hardening and its control.

We are now in the period where hundredths and thousandths of a percent are being dealt with. An interesting case of this sort occurs with lead. Schumacher and Bouton[1] and Dean and Ryjord[2] three years ago, described to our readers the effect of some 0.04% calcium in lead, which produced an age-hardening lead alloy of value for cable sheath. Singleton and Jones[3] now describe what about 0.06% of tellurium does when alloyed with lead—if it is proper to use the term "alloying" for the addition of an element like tellurium which may perhaps not be strictly defined as a metallic element.

The outstanding effect of these "traces" of tellurium is to raise the recrystallization temperature of lead—much as silver does that of copper—so that instead of softening at room temperature as pure lead does, the lead containing tellurium will work-harden and retain that hardness. Thus, instead of giving way under small loads, and continuing to give way, as is characteristic of ordinary lead, the new alloy will strengthen under deformation. This is claimed to be a distinct advantage in resistance of lead pipe to bursting when frozen, for example, though the freezing tests cited are not considered by some lead experts to duplicate service conditions sufficiently closely to be entirely conclusive.

Offhand, the tellurium lead would not appear to have much, if any, advantage over the lead-calcium alloy for cable sheath, since the endurance limit of extruded material, as given by Singleton and Jones, is not as good as that found by Dean and Ryjord for their alloy. Nor is it stronger in tension in the hard-rolled condition than is the 8% antimony alloy. One might expect that its ability to strain harden would make it better in resistance to "creep" under long-continued loads than some of the other lead alloys, but, probably because of the long time necessary for reliable creep tests, Singleton and Jones do not touch on creep properties.

They do claim that it is a notable competitor of chemical lead, for, at least in concentrated sulphuric acid, it is said to show better corrosion resistance than pure lead, and is about twice as strong. In a sulphuric acid plant, the loss of weight was found to be but one-seventh of that of the best chemical lead. Its behavior in dilute sulphuric acid is not described. The commercial possibilities of the new lead are not yet made very clear. However, it is hinted that the beneficial effect of tellurium is shown to some degree in Pb Sn, Pb Sb, Pb Sb Cd and Pb Sn Cd alloys.

It will be interesting to know whether better lead-base bearing alloys, type metal, etc., are in prospect through the use of tellurium.

At any rate, the properties so far reported are interesting enough so that the alloy serves as a good example of the "importance of little things" in metallurgy and to remind us that the possibilities in even the simple binary alloys have not yet been exhausted, even though we might have thought that they must all have been sufficiently studied to establish their properties.—H. W. GILLETT

[1] *Metals & Alloys*, Vol. 1, March, 1930, pages 405-409.
[2] *Metals & Alloys*, Vol. 1, March, 1930, pages 410-414.
[3] W. Singleton & B. Jones. Some effects of the addition of tellurium to lead. *Advance copy* No. 633, *Institute of Metals*, 1933, 10 pages.

Oh Heck! What's the Use?

POWER PLANT ENGINEERING for April, 1933, page 159, contains an editorial on Synthetic Metals in the Power Plant, which says, "Thus we may expect laboratory discoveries of metals that will greatly reduce electric and heat transfer losses, that are practically immune to corrosion or action of acids, that will maintain their strength at extremely high temperatures, that combine strength and low specific gravity to a degree not known today, that are non-combustible heat insulators, that will not transmit sound or other vibrations, yet have the strength of metals like iron, that are *slow to crystallize under reversing stress.*" (italics ours.)

When an engineering editor still clings to the crystallization idea in discussing fatigue in spite of all the attempts of workers in fatigue to educate the engineering public toward correct view points and phraseology, we are inclined to think that the only way to get the idea across is to hire Eddie Cantor or Kate Smith to broadcast it.—H. W. GILLETT

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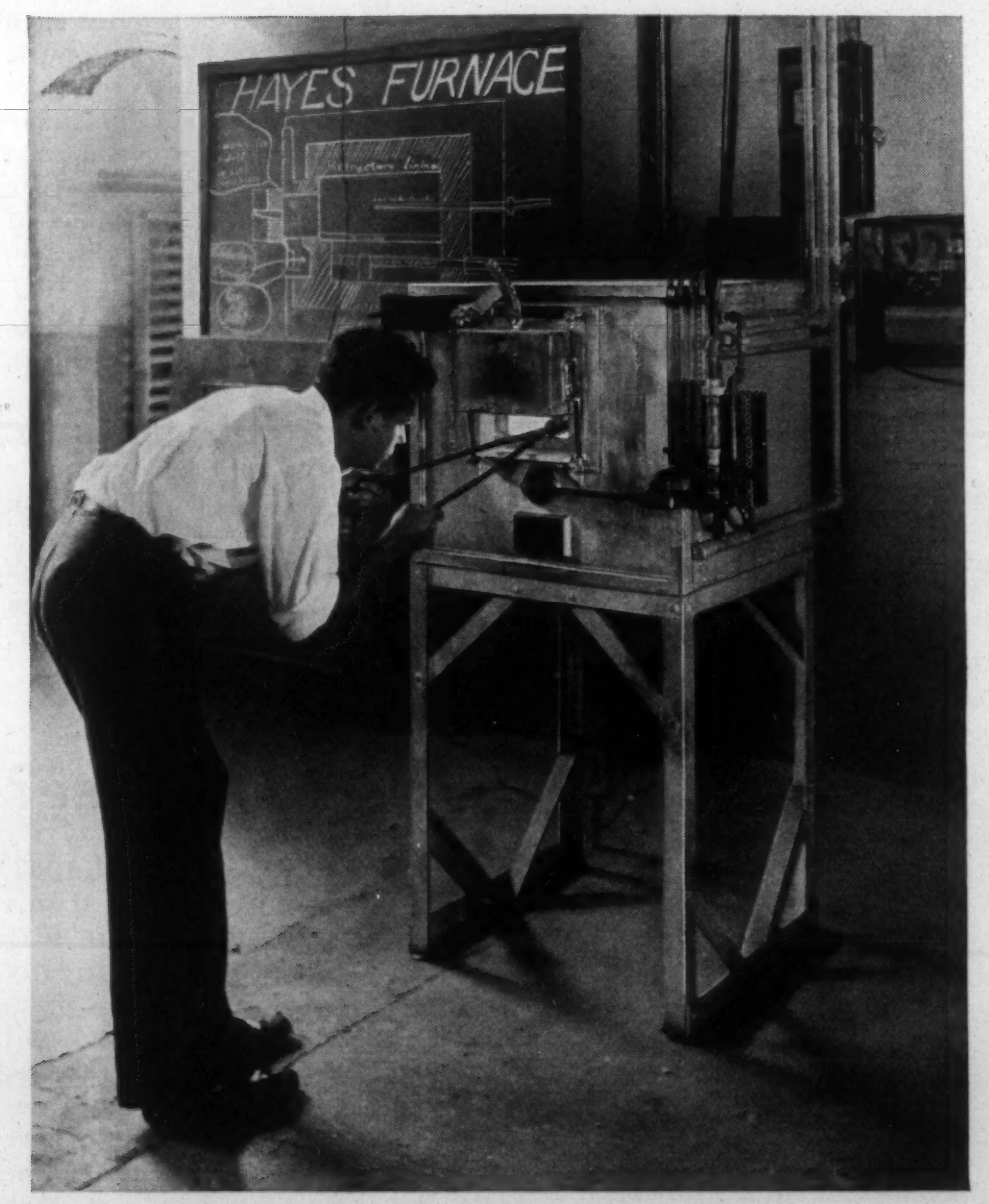

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MONOLITHIC LININGS for INDUCTION Furnaces Melting Non-ferrous Metals

By P. S. KINGSLEY*

DUE to the increasing use of the Ajax Wyatt furnace for copper and brass melting, considerable work is being done on improving the refractory lining so essential to the operation of the furnace. A good deal of progress has been made in developing cements to be used for these linings, but a corresponding advance in the technique of using these cements has been lacking. There are several good cements on the market for both brass and high copper mixtures. Those in most common use are: mixtures of chrome ore and refractory clay for brass melting; and fused magnesia for high copper and pure copper melting. These cements are prepared from closely controlled raw materials, purified and graded for grain size; and marketed under trade names by several manufacturers. Those most popular at present seem to be: Johns Manville's No. 34 Cement and Refractory & Engineering Company's No. 3450 Cement for brass melting; and Norton Company's fused magnesia cements for copper and high copper mixtures.

The manufacturer has control of the following in the preparation of the cements:

1. Choice of the raw material
2. Physical and chemical qualities of the raw materials
3. Grain size of the cements
4. Choice and amount of bonding materials

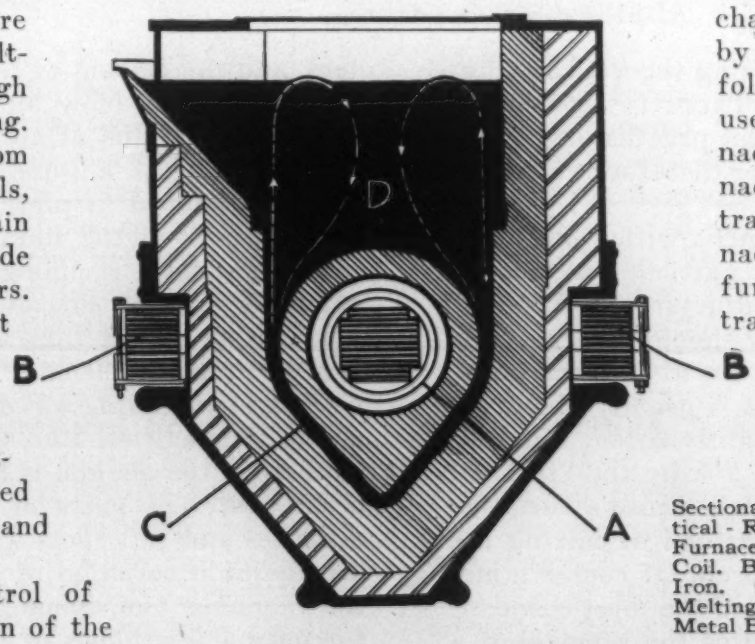
Some of these factors can be varied by the manufacturer and others are inherent in the materials used. These factors are all closely watched, so most of the cements now on the market represent the best efforts of the manufacturer and have surprisingly little variation.

The use of the cement by the consumer, however, has not received as much attention; in spite of the fact that he has control of the major elements governing the success or failure of the lining as measured by the amount of metal cast. It would be expected that both phases would be developed simultaneously, but the manufacturers have far out distanced the consumer. Comparatively recently has work been started from the consumer's end.

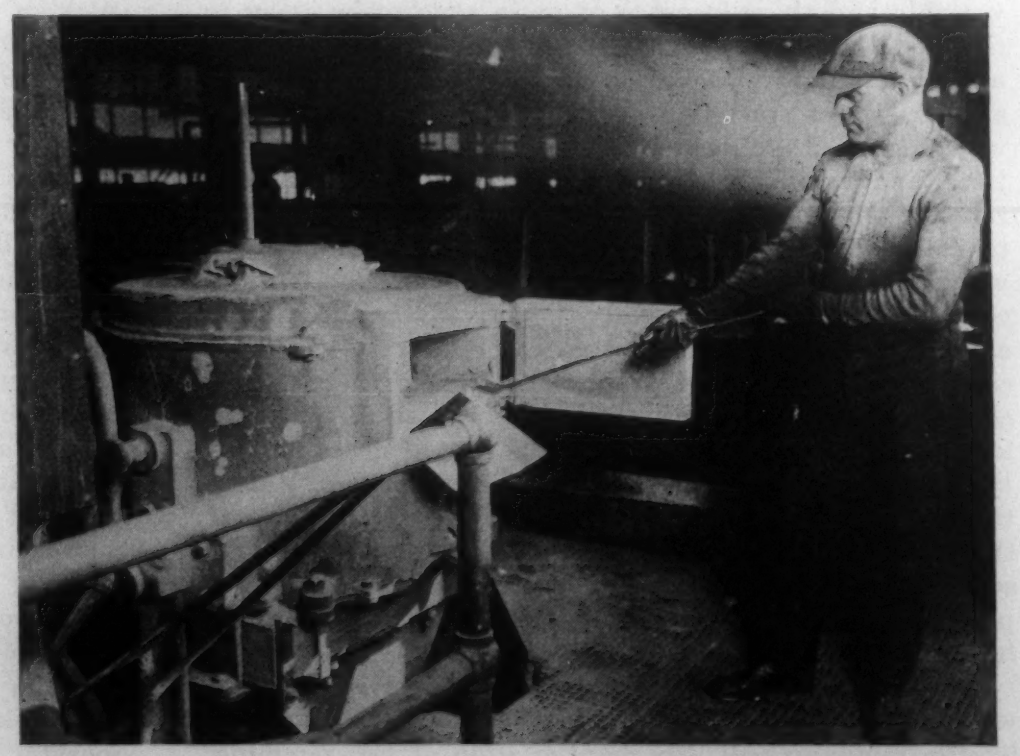
*Rome, N.Y.

Before going further with this, the main reason for this article: the author wishes to sketch the working of the Ajax Wyatt furnace and define some terms, which have grown from common usage to have a definite meaning in relation to these furnaces.

The essential parts of the furnace from a refractory viewpoint: a crucible for holding the molten metal, and a V-shaped vertical channel connecting the two sides of the bottom of the crucible. Heat is generated by the resistance of the molten metal in the channel to an induced current from a primary coil. The molten metal in the channel acts as the secondary of a transformer, the primary of which is the coil placed within the secondary loop. The heated molten metal in the channel is forced up into the crucible by the motor and pinch effect. In the following discussion, the author will use the terms: "bottom of the furnace," meaning that part of the furnace below the lower plane of the transformer; "middle of the furnace," meaning that section of the furnace from the lower plane of the transformer to the floor of the crucible; "crucible of the furnace," meaning that part of the furnace from the crucible to the top of the furnace; "cover," meaning the entire cover of the furnace; "secondary" meaning the V-



Sectional View of Vertical - Ring Induction Furnace. A—Primary Coil. B—Transformer Iron. C—Secondary Melting Channel. D—Metal Bath.



(Courtesy Chase Brass & Copper Co.)

shaped secondary channel; "sticking the furnace," meaning priming the furnace with molten metal; and "shell of the furnace," meaning the outside metal wall.

(Courtesy Chase Brass & Copper Co.)

The procedure in preparing a furnace for lining is to cover the bottom shell on the inside with asbestos paper and then fit in one thickness of insulating brick; covering bottom, sides and walls. Next a sufficient quantity of cement is mixed with water (if the cement is shipped dry), and a small amount of cement put in on top of the insulating brick, rammed in place with an air hammer and suitable ramming tools. This is continued, the secondary form being put in place; and the asbestos shell for the primary coil as these parts are reached in building up the furnace. When the bottom and middle of the furnace are completed, the crucible shell is bolted to the bottom shell and a metal form placed inside; the ramming being continued to the top of the furnace. This gives a lining theoretically uniform and one piece throughout. There is room for a great deal of variation from the best practice in each of the different steps of this process; therefore each step will be taken up separately.

The first step is mixing the cement with water. The amount of water required by the particular cement is usually recommended by the manufacturer and should be followed very closely. The water should be accurately measured and not left to the judgment of the men doing the work. After mixing, the cement is usually about the consistency of molding sand or slightly drier; but it is impossible to detect a difference of 2% by the "feel" of the cement and even this variation will cause a variation in the results of the lining. The method of mixing the cement should be very carefully chosen. Of course a mechanical mixer is the best solution and the most economical in the author's opinion; because of the removal of a variable and the allowance of more time to be spent in the installation of the cement. If the cement is to be mixed by hand, it should be spread out on a clean floor and the water sprinkled over it with a common garden watering can; adding only a small amount of water at a time, and raking the cement over with a steel garden rake. If too much water is added at one time, the cement tends to ball up with a resulting uneven distribution of water. Some users claim an advantage in mixing the cement the night before and allowing it to temper. The only advantage is a more even water distribution. This can be accomplished by proper mixing and there is less chance of loss of water through evaporation with the morning mix. Evaporation has to be watched very closely, the cement being kept covered with wet burlap. Variation in moisture content, the possibility of freezing, and the segregation of the different components are the disadvantages of premoistened cements. These outweigh any possible advantage gained by the addition of a fluid binder.

The next step is ramming the cement in place. The variables which enter in are: the strength of the blow hit by the ramming tool, the manipulation of the ramming tool, and the amount of cement rammed at one time. The strength of the blow hit by the ramming tool is determined by the kind of air hammer used and the air pressure. Too great a force will cause flow of the cement already rammed in place, resulting in a crack or plane of weakness in the lining. Because of this some users prefer balanced ramming; that is, an operator and gun ramming on each side of the furnace at the same time. The author found that when using an Ingersoll Rand No. 300 riveting hammer with 100 pounds air pressure, no flow of the lining was detected. It is necessary to have a large enough air line so that no drop in pressure occurs when the air gun is being used. If such a drop does occur, different parts of the lining will have different densities and soft spots will be found. There seems to be considerable variation of opinion in the manipulation of the ramming tool. Some operators recommend ramming for only a few blows of the gun in one place and then picking up the gun and tool and ramming in a different place, continuing this until the layer is all rammed in. Other operators meet with good success by ramming somewhat longer in each spot and finally "walking the gun" or sliding the ramming tool along the surface of the layer to smooth and pack it all in place. There is a happy medium between the two practices and most operators achieve this themselves.

The question of the amount of cement rammed at one time is one of the most important in the whole procedure. The ideal method would be to ram each bit of cement by itself, but this is impractical. If too much cement is put in at one time, that on top of the layer will be rammed harder and consequently will have a greater density than that on the bottom. Therefore the top of one layer, adjacent to the bottom of the next, will have a different coefficient of expansion and a layer crack will tend to form. If the top of each layer is well broken up with a sharp pointed pick, the cement of the next layer will bind into it and help prevent these cracks. It was found that a layer of approximately 3 inches, with the surface well broken, will not form layer cracks and will give the operator ample time to thoroughly ram the furnace.

(Courtesy Norton Company)

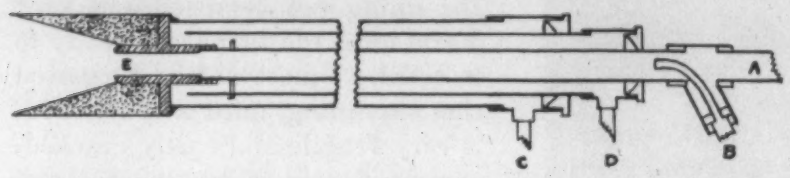
In the case of magnesia cement, the lining should be carried up to within an inch of the top of the crucible shell; and in the case of a chrome ore base cement, flush with the top of the shell. This will allow room for the permanent expansion which takes place in magnesia cements on exposure to heat. Chrome cements do not show this growth; and the close joint between the walls of the crucible and the cover of the furnace, strengthens the top of the walls, also reducing heat loss.

The wooden core used to form the secondary channel should be sufficiently strong to withstand crushing by the air hammer and should be shellaced to prevent its absorbing water from the lining. It should be held rigid in its clamps so that no movement, with a subsequent crack, can take place. It should never be disturbed, after once in place, until it is burned out when the lining is dried. The asbestos shell covering the primary coil of the transformer should be reinforced and held rigidly in place to prevent any movement during ramming.

The next step in the preparation of the furnace is drying out the lining. The form, around which the walls of the crucible are rammed, is removed and the furnace allowed to dry at room temperature. At least 48 hours should be allowed for the removal of excess moisture and the chemical changes to take place in the cement. The transformer is usually assembled and placed in place during this interval. Then the wooden core of the secondary channel is burned out. Some operators use an acetylene torch, some use pure oxygen gas for this purpose. The author prefers an electrical resistance strip, threaded through the core before it is rammed in place. Heat is generated in this strip by an induced current from the primary coil. This generates less heat and at a slower rate than a torch, therefore it is easier on the lining. The furnace is then heated to at least 200°F. for a period of 48 hours and then to at least 400° for an additional 48 hours. This drives off the moisture in the cement and thoroughly bakes it. Some users do this by placing the entire furnace in an oven, but the author prefers using the same resistance ribbon, in the secondary channel, which was used to burn out the wooden core. This supplies the necessary heat for the first period and a resistance coil is placed in the crucible for the second period. In this way the lining can be dried and kept warm until the furnace is ready to be used. It must not be forgotten that the lining, until it is vitrified, is very fragile and easily cracked, more so after it has been dried than before. If possible, the furnace should not be moved, much less subjected to any jar after it has dried out. One user has found it necessary to equip the cradles, on which the furnaces are moved, with coil springs to remove the shocks from the floor.

The next step is heating the lining. No matter what type of heating apparatus is used, this operation cannot be done too carefully. Whether an oil torch or a gas torch is used, the flame should be turned low at the start and gradually increased as the lining warms up. Any thermal shock is apt to cause cracks to appear with subsequent lining failures. If possible, a torch should be used which forces the flame all the way through the secondary channel. This is practically impossible with an oil torch, but can be accomplished with gas. The necessity for thoroughly heating the secondary channel cannot be stressed too strongly. This part of the lining has to withstand the highest temperature, the greatest metal penetration, and the most erosion. Yet it receives the least heat in the average preparation of the furnace. Using an oil torch for a period of 10 hours, the highest temperature obtained in the bottom of the channel was 900°F. When the furnace is "stuck," the molten metal at 1900° or 2000° gives too great a thermal shock to this part of the furnace. Using a gas torch, firing directly into the channel for 6 hours, a temperature of 1800° was attained. In connection with the gas torch, it is unfortunate that there is not an adequate one on the market. A torch can be built at a reasonable cost, however, provided high pressure gas and air are available. The difficulty arises from the necessity of firing directly into the channel and burning the gas all the way through the channel. This allows flame to emerge from the other end of the channel, thus heating the crucible of the furnace. In order to do this the burner end of the torch has to be placed within a couple of inches of the bottom of the furnace. This prevents the pick-up of any secondary air at the burner, and forces the supplying of all the air necessary for complete combustion at the inlet end of the torch. It is impossible to do this through inspiration unless an excessively large inspirator is used. A much better method is the introduction of high pressure air through a jet in a "Y" connection at the inlet end. Closer control of combustion is possible by this method through control of the air by a needle valve. The burner end of the torch, being inside of the crucible, has to be made of heat resisting metal or water cooled. The pipe supplying the gas-air mixture has to be cooled also to prevent cracking of the gas or pre-ignition of the mixture. This can be done by having 3 concentric pipes; sending water down through the outside one, which is welded to the burner, and back through the second one.

The gas-air mixture is sent through the center pipe, which carries the burner on one end and the "Y" connection on the other end. The burner is protected by a heat resisting sleeve, refractory lined.



Sectional View of Gas Torch. A—Gas Inlet; B—Air Inlet; C—Water Inlet; D—Water Outlet; E—Burner.

With this torch, the heating can be started very slowly with a luminous flame and gradually increased, shifting the torch from one side of the channel to the other, until the whole is at the metal temperature. The exhaust gases and flame from the channel heat the crucible sufficiently. With the reduced gas rates, which are now almost universally in effect, it is only slightly more expensive than oil heat, and when the operator's time is considered the differential is still smaller. The author fully believes that it is economically sound to spend time enough to heat the channel to at least the same temperature as the molten metal. He has been unable to thoroughly check the results obtained by using gas and heating to the metal temperature before "sticking," but the test furnaces indicate a much better life than that attained by the oil torch fired furnaces.

In the operation of the furnace, care should be exercised to avoid any jarring of the lining from dropping heavy pieces of metal into the furnace; also any thermal shock from air currents on the hot cement. The lining should be kept clean by chipping the slag off the crucible walls and scraping the secondary channel with a metal strip. This should be done with great care so that the surface of the lining is not broken. Once the vitrified layer is broken through, erosion rapidly takes place due to the softness of the non-vitrified cement.

One of the most important factors in increasing lining life is the keeping of accurate records of the life of each lining and the reason for its failure. Very little progress can be made in this work without the information these records give, because of the large number of variables possible in each lining. The segregation of the cause of any one failure is almost impossible. By determining the location and character of several successive failures, the cause can be reasonably accurately determined. One of the most frequent failures, particularly in the high copper furnaces, is a layer crack failure through the middle of the furnace. This can be due to a variety of causes, the most likely of which are: Too much cement in the layer, not breaking up the top of the layer sufficiently, middle plate of the furnace not strong enough to support the weight of the bottom of the furnace without movement, or evaporation of moisture from the top of the layer during the noon hour if the furnace is left at this point. Each of these and all other possibilities should be investigated until the particular one causing the failure is determined.

It is all too common to neglect the refractory problem and leave it to the casting shop foreman or the boss mason. These men have too many other duties to devote the time necessary to this one problem. There should be some one with ample time to follow the records of the furnace life obtained and to determine the causes of failure. The author believes that the length of life of the linings now in use can be markedly increased. It is possible that better cements will be developed, but probably not until the cause of failure of present cements is determined and the limit of their life is learned.

Rustless Iron Wins in Patent Suit

A suit instituted in 1929 by the Electro Metallurgical Company and the American Stainless Steel Company against the Rustless Iron Corporation was brought to a close by a decision in favor of the defendant in the United States District Court on February 29th. This decision establishes the right of an independent unit of the steel trade to manufacture stainless steel, rustless iron and essentially all chromium and chromium-nickel alloys under its own patents and those of the Chemical Foundation, of which the Rustless Iron Corporation is a licensee.

Prize Winning Papers on Arc Welding In Book Form

The prize winning papers submitted in the Second Lincoln Prize Competition have been assembled and published in book form under the title "Designing for Arc Welding." The use of arc welded alloys to resist corrosion, the substitution of arc welded steel for aluminum without weight increase, the welding of high tensile steels and structural design for the resistance of earthquake shocks are among the new developments which are discussed.

These papers were discussed individually in the "Current Metallurgical Abstracts" section of *Metals & Alloys*.

Correction

Due to an oversight these footnotes were omitted from the article by Johnson and Oberg which appeared in our March issue:

[1] R. Sergeson. Behavior of Some Irons and Steels under Impact at Low Temperatures. *American Society for Steel Treating*, Vol. 19, Feb. 1932, pages 368-384.

[2] H. W. Russell. Effect of Low Temperatures on Metals and Alloys. *Symposium on Effect of Temperature. American Society for Testing Materials and American Society of Mechanical Engineers*, 1931, 658-682.

[3] H. W. Russell & W. A. Welcker. Endurance and Other Properties at Low Temperatures of Some Alloys for Aircraft Use. *Technical Note* No. 381. *National Advisory Committee for Aeronautics*, June 1931, 13 pages.

[4] R. L. Templin & D. A. Paul. Alloys at Elevated Temperatures. *Symposium on Effect of Temperature on Metals. American Society for Testing Materials and American Society of Mechanical Engineers*, 1931, pages 290-315.

[5] F. Bollenrath. On the Influence of Temperature on the Elastic Behavior of Various Wrought Light Metal Alloys. *Journal Institute of Metals*, Vol. 48, 1932, pages 255-272.

A. S. T. M. Awards Medal

The award of the Charles B. Dudley Medal of the American Society for Testing Materials, given each year in recognition of the outstanding paper recording original research presented before the Society in the previous year, has been made to Samuel Epstein for his paper on Embrittlement of Hot Galvanized Structural Steel. The medal will be presented at the annual meeting in Chicago in June.

Mr. Epstein, a former member of the metallurgical staff of the Bureau of Standards, and of the Illinois Steel Co., is metallurgist at Battelle Memorial Institute and one of the METALS & ALLOYS abstractors. The work for which the medal was awarded was carried out at Battelle under the sponsorship, first of the Utilities Research Commission and later of the A.S.T.M., through its Embrittlement sub-committee, and culminated in the addition to the specifications for galvanized structural steel of a tentative method for the determination of embrittlement, and the statement of means for the avoidance of embrittlement, based on the work of Mr. Epstein and his coöperators.

New Company

All Ryan, Scully & Company products will be manufactured, sold and installed by the new R-S Products Corporation, according to an announcement sent out recently. F. J. Ryan and G. F. Beach, President and Chief Engineer respectively, of Ryan, Scully & Company, have assumed like positions with the new organization.

Foundrymen To Meet During Century of Progress

When the American Foundrymen's Association Convention opens in Chicago on June 20th, the Century of Progress will have been running three weeks, and the foundrymen who attend the meeting will be assured of a program of interesting and diversified activities.

The Nature of the Solid Solution of Aluminum in Silver

By CHARLES S. BARRETT*

THE NATURE of solid solutions is one of the most important problems in the study of alloys. Among the solid solutions in which the solvent is a pure metal only two types are thus far certain. These are the substitutional, as typified by the α-brass solid solution, and the interstitial, as typified by the solid solution of carbon in γ-iron, austenite. There is no undisputed evidence at the present time for departures from these types; nor is there any undisputed evidence for the existence of solute molecules in such solid solutions.[1] The importance of the problem demands a close study of any proposed new types.

The recent work of Phelps and Davey is a case in point. The data[2] obtained by these workers show a lack of agreement between the density calculated from composition and lattice dimension as determined by X-rays and the density measured directly, from which it was concluded that this solid solution is not a "normal" type, but one in which molecules of a phase of intermediate composition replace groups of silver atoms. The precise details of the argument may be found in the paper cited.

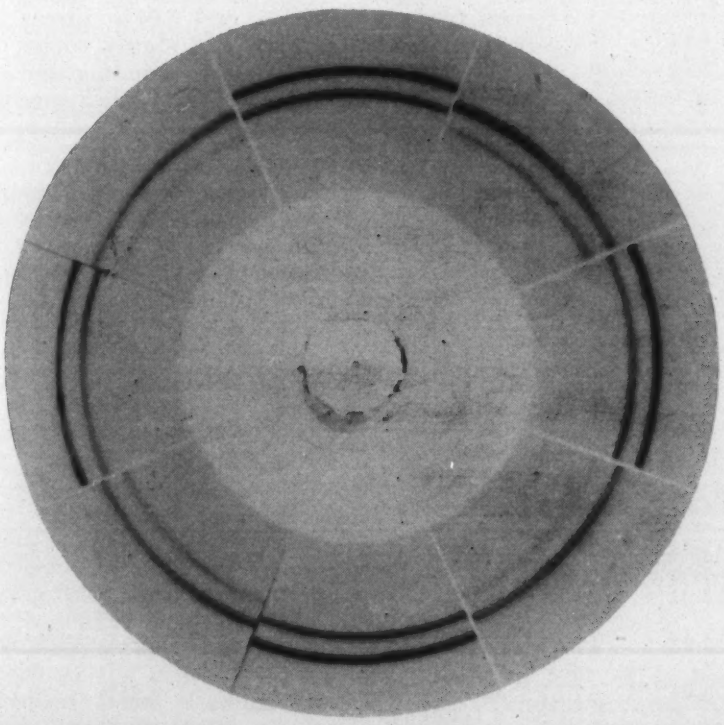


Fig. 1. Diffraction patterns for slowly cooled alloys. Those at the 3, 6, 9, 12 o'clock positions were exposed to 5.04% alloy; the others, to 3.01% alloy.

The present work is a new experimental study of this solid solution, bringing to bear upon the problem more precise X-ray methods and exercising more extensive precautions in the preparation and treatment of the alloys.

*Bureau of Metallurgical Research, Carnegie Institute of Technology, Pittsburgh, Pa.

[1] See for example R. F. Mehl & C. S. Barrett. *Transactions American Institute Mining & Metallurgical Engineers, Institute of Metals Division,* Vol. 89, 1930, pages 203-206.

G. Wasserman. *Zeitschrift für Metallkunde,* Vol. 22, 1930, pages 158-160.

[2] R. T. Phelps & W. P. Davey. *Transactions American Institute Mining & Metallurgical Engineers,* Vol. 99, 1932, pages 234-245; discussion, pages 245-263.

Preparation and Treatment of Alloys

The alloys were made from high purity silver and high purity aluminum. The silver carried an analysis of 99.99 Ag; the aluminum was furnished by the Aluminum Company of America and was of their 99.97% quality. To increase the precision of the density measurements and decrease the danger of alloy contamination generous sized ingots, 120 grams each, were made. The alloys were melted in graphite crucibles in a muffle furnace. To prevent oxidation an atmosphere of natural gas was maintained in the furnace. The alloys were vigorously stirred with a graphite rod and chill cast in a cylindrical copper mold, the mold having been flushed with natural gas and the pouring operation conducted under a blanket of gas. Although a scum was observed to form on the alloys, it was prevented from entering the mold. The 3.01% and 5.04% aluminum ingots, upon which density measurements were made, showed no trace of aluminum oxide upon analysis. Table I indicates the composition of the materials weighed into the crucible and the analysis of the final alloy after homogenization, and shows that there was but little loss of aluminum. Spectroscopic analysis showed that the alloys had picked up no impurities during the process.

The cylindrical ingots were turned on a lathe to a reduction of ⅛" in diameter and annealed in graphite at 750°C. for one week. Each day they were removed and hammered while hot to a reduction of about 1/16" in thickness, then quenched, filed clean, and the annealing resumed. At the conclusion of this treatment the ingots were ⅛" to 3/16" in thickness, reduced from an initial diameter of 9/16".

The ingots as cast had, of course, unsatisfactory densities, but as the hammering and annealing continued, the densities approached constant values. Measured prior to the last reduction in thickness, the densities differed from the densities subsequent to this reduction by less than the probable experimental error, and it was safe to conclude that further reduction was unnecessary. Numerous cracks developed in the 5.5% and 6.8% ingots, so their densities were not measured. The final homogenization treatment was a 3-hour soak at 710° ± 5°C., followed by simultaneous quenching of all the alloys in water at 15°C. The entire surface of the ingots was filed and ground on emery paper, with precautions taken against introducing strains in the operation. Samples of 6 grams each were removed from the extreme top and bottom of each ingot and analyzed, with the results as shown in Table I, column 2. These analyses prove the absence of segregation from the top to the bottom of the ingot, while the chill casting, hammering, annealing, and final skinning guaranteed uniform composition throughout the thickness of the ingots.

TABLE I. MEASURED DENSITIES

weight % aluminum intended	weight % aluminum by analysis	atomic % aluminum	preliminary density (with CCl_4)	final density (with H_2O)
3.08	3.01 (top)	11.04	9.728	9.727
	3.01 (bottom)	11.04	9.738	9.728
5.04	5.03 (top)	17.48	9.268	9.275
	5.04 (bottom)	17.51	9.273	9.274
5.65	5.51 (top)	....		
	5.58 (bottom)	19.11		
6.84	6.80 (bottom)	22.59		
silver			10.49	

Determination of Density

The preliminary densities were determined by the loss in weight of the alloys in carbon tetrachloride (Eastman's best grade), the density of which was taken from the International Critical Tables. The ingots were cut into top and bottom halves of about 30 grams each, filed, cleaned, and outgased in carbon tetrachloride under a vacuum, and precautions were taken to keep the balance case practically free of CCl_4 vapor. The final densities were measured in vacuum-boiled distilled water, the samples having been boiled for 20 minutes in distilled water under a vacuum, then suspended on the wire on the balance without exposure to the air. The balance and weights were calibrated against calibrated standard weights to 1/10 milligram, and the temperatures measured on a standardized thermometer. The densities are given in Table 1, referred to the samples at 24°C. in vacuum.

X-Ray Determination of Lattice Dimensions

The X-ray measurements were made on a precision camera of the back reflection type.[3]

Photographic plates were used for all the important measurements to avoid film shrinkage. The plates were mounted on a revolving disk under a sector having four openings constructed in such a way that the diffraction rings were split into four arcs equally spaced around a circle. It was thus possible to measure two diameters of the rings standing at 90° to each other and to make the important exposures on a single plate (see Fig. 1). The specimen holder was arranged to receive a plane surface metallographic specimen, to maintain its plane perpendicular to the axis of the rotating photographic plate, and to rotate the specimen about an axis perpendicular to the specimen surface. The specimen holder and the plate holder were mounted on ball bearings and were carefully de-

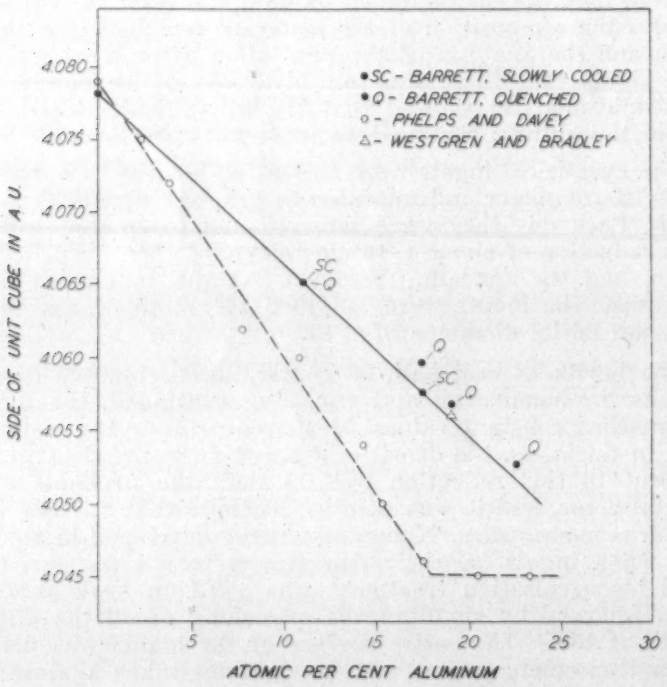


Fig. 2. X-ray results. The solid line is drawn through the data for slowly cooled specimens because of their greater precision.

signed to maintain a constant distance between specimen and plate. In this work the distance was made approximately 8 cm. and was measured by a micrometer to a few ten thousandths of an inch. The X-rays entered the camera through a pinhole ½ mm. in diameter and 4 mm. in length, located concentrically with the axis of the revolving plate holder and at a position fulfilling the Bragg focussing condition for the lines to be measured. The camera was operated with an X-ray tube of the electron type which was run at 50,000 volts and 30 milliamperes. Copper radiation was used and the reflections of $CuK\alpha_1$ and $CuK\alpha_2$ were obtained from the {115}, {333} planes.** The diffraction patterns were measured on a comparator reading directly to microns with a microscope giving a magnification of 1.5. Computations were made using the wave length values $CuK\alpha_2 = 1.541232$ A.U., $CuK\alpha_1 = 1.537395$ A.U.[4] The slight correction for the deviation of the index of refraction from unity was neglected.

Preparation of the samples for the X-ray exposures consisted of grinding on successively finer emery paper from No. 1 to No. 0000 followed by an etch in 50% nitric acid, this sequence being repeated 2 or 3 times until it effected a total

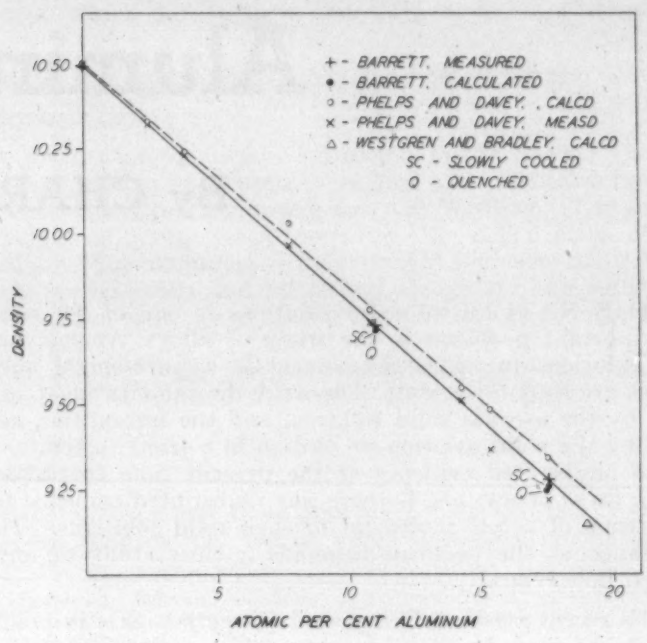


Fig. 3. Comparison of densities measured and densities calculated on the simple substitutional theory.

reduction in thickness of 0.010" to 0.015" of which 0.003" to 0.004" was removed in the final etch. In spite of these precautions to expose a surface free from strains, the quenched specimens did not yield sharp diffraction lines. After these exposures had been made, the 3.01% and 5.04% pieces were replaced in graphite, reheated to 600° and slowly cooled over a period of 40 hours, after which the above grinding and etching treatments were repeated. These slowly cooled specimens yielded the sharp patterns reproduced in Fig. 1.

The X-ray results are given in Table II and are plotted in Fig. 2. All available data of other observers are also included in the figure. The accuracy of the measurements varied considerably with the different specimens. The 3.01% and 5.04% alloys in the slowly cooled condition could be read with great precision; the difference between the values of a_0 calculated

TABLE II. LATTICE DIMENSIONS AND CALCULATED DENSITIES

weight % aluminum	atomic % aluminum	treatment	side of unit cube in A. U.	calculated density (simple substitution)	observed density
3.01	11.04	quenched from 710°C.	4.0655	9.712	9.727
3.01	11.04	slowly cooled from 600°C.	4.0651	9.715	9.728
5.03	17.48	quenched from 710°C.	4.0596	9.241	9.275
5.04	17.51	slowly cooled from 600°C.	4.0576	9.252	9.274
5.58	19.12	quenched from 710°C.	4.0568		
6.80	22.59	quenched from 710°C.	4.0527		
silver		quenched from 710°C.	4.0782	10.491	

from the $K\alpha_1$ and from the $K\alpha_2$ lines was less than 0.0002 A.U., and measurements of the plate by 2 different observers gave agreement in a_0 to 1 part in 80,000. The accuracy with the quenched specimens was much less, probably about ±0.001 A.U., for with broad lines and coarse grained materials such as these the distribution of intensity within the lines was unreliable.

(Continued on Page 74)

[3] G. S. Sachs & J. Weerts. *Zeitschrift für Physik*, Vol. 64, 1932, pages 344-358, 481-490.

C. S. Barrett & H. F. Kaiser. *Physical Review*, Vol. 37, 1931, pages 1636-1637.

**The Kα radiation from nickel would have given slightly increased dispersion but would have been somewhat inconvenient to use.

[4] Siegbahn. Spektroskopie der Röntgenstrahlen. Second Edition. Julius Springer, Berlin, 1931.

EARLY CHEMISTRY and CHEMISTS in the IRON and STEEL INDUSTRIES — No. 3

(Continued from the April issue)

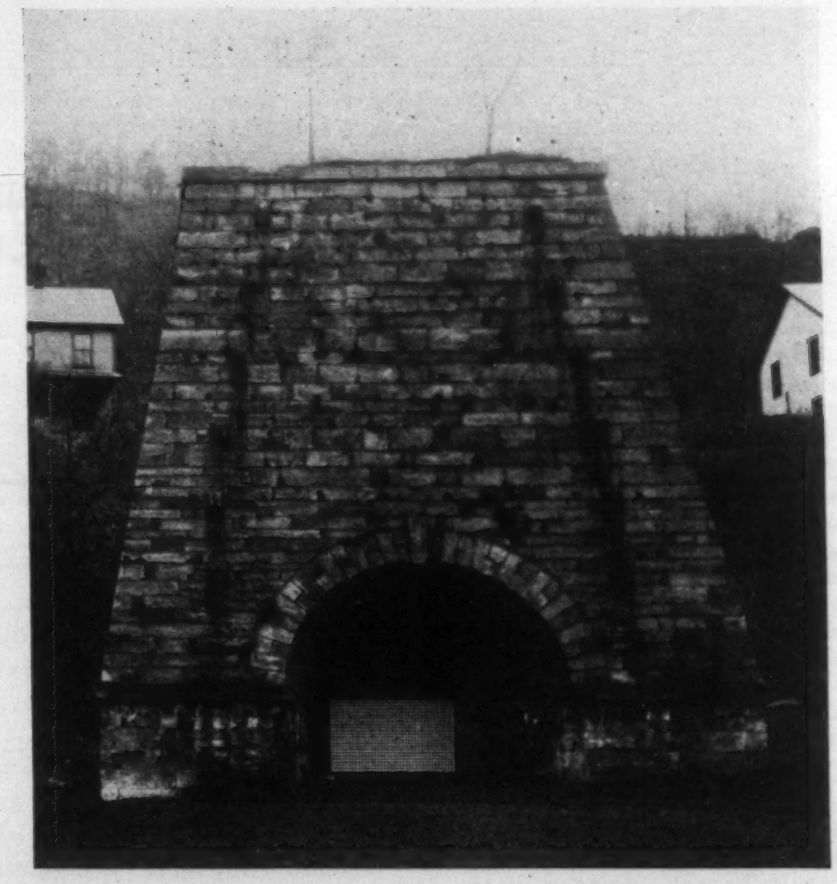
SCENES Around the Early Blast Furnaces

By L. W. SPRING and L. E. GILMORE

TWO interesting letters from George C. Davis, Analytical and Consulting Chemist of Philadelphia, depict the old days when he was a blast furnace chemist.

"In May 1889 I became chemist of the Addyston Pipe & Steel Co. which was a modern plant 13 miles below Cincinnati on the Ohio river. It is of this period (1880-1900), but chiefly, of course of the last decade that I have some first hand knowledge. At that time there were few if any 'self contained' plants such as we now have. These began some ten years later being brought about largely by the work of two lawyers. I refer to Judge Gary who advised John W. Gates and to Judge Dill of N. J. whose writings on corporation law had so much influence on J. P. Morgan, Sr. There were many small plants. Forges making wrought iron by the direct process were still plentiful and while there were modern blast furnaces with steel shells and fire brick stoves, there were many old brick or stone stacks with iron pipe stoves. In fact, this type continued until late in the 1890 decade.

"At this time Cincinnati was an important center of the foundry iron trade. This was due to three causes. First the building of three railroads: the C. & O. completed about 1873, the Cincinnati Southern to Chattanooga about 1878 and the N. & W. about 1892. Secondly the industrial development of the South and thirdly the men in Cincinnati of whom I will say more later in this article. Involved in this was the real estate boom in the South which began in the late 1880's and went to smash at the time of the Baring failure in 1891. This boom extended from Virginia to Kentucky, Tennessee, and Alabama. In most of these towns was either a blast furnace or rolling mill. A good example of this was Ft. Payne, Ala., where much Boston money was lost. There was a thin vein of ore there of which enough was mined to last a furnace several minutes, but it looked like a lot to town lot buyers from the North. The story of this boom has been well told in a series of articles in the Engineering and Mining Journal, sometime between 1900-10 I think. I was in Virginia and Tennessee from 1894 to 1896 and saw the disconsolate remains of many of these boom towns and knew some of the people who lived through that period. There was much English capital involved in such places as Middlesborough, Kentucky (Watts Iron & Steel Syn.), the Embreeville Estate in Tennessee and Dayton C. & I. Co. also in Tennessee.



The Farrandsville Furnace built about 1835 in Colebrook Township, Pa. (Courtesy Harbison-Walker Refractories Company.)

"No account of that period would be complete without some reference to the English 'remittance men' of whom there were many in the South at that time. To explain the term I will say they were younger sons not wanted at home for good reasons and who were sent to this country with a quarterly allowance as long as they stayed here. To do justice to these men would require the genius of Owen Wister or O. Henry and I am quite sure an account of their activities would not be printed in any religious paper. I knew a few of them,—likeable chaps they were but a trifle wild.

"Some of these boom town furnaces were operated as late as 1918 but as a rule they were poorly located even for the then existing conditions. To one who knew these towns the more recent happenings in Florida seemed strangely familiar.

I recall one of these English furnaces which was operated after the boom. In front of the tap hole of the furnace was a small spring not drained. This resulted in several boils until the cause was discovered and I can assure you that thirty tons of molten iron on the rampage makes lots of excitement. The stock shed was three feet too low and no box car could be unloaded without unshipping the brake rod. The ore washers were on high ground so the needed water could be pumped up hill and there was no heat in the manager's house except fire places. Above the furnace on the hillside were some excavations in rock. This was to have been the local 'Lake Shore Drive' where the Four Hundred were to drive on pleasant days in their landaus and broughams.

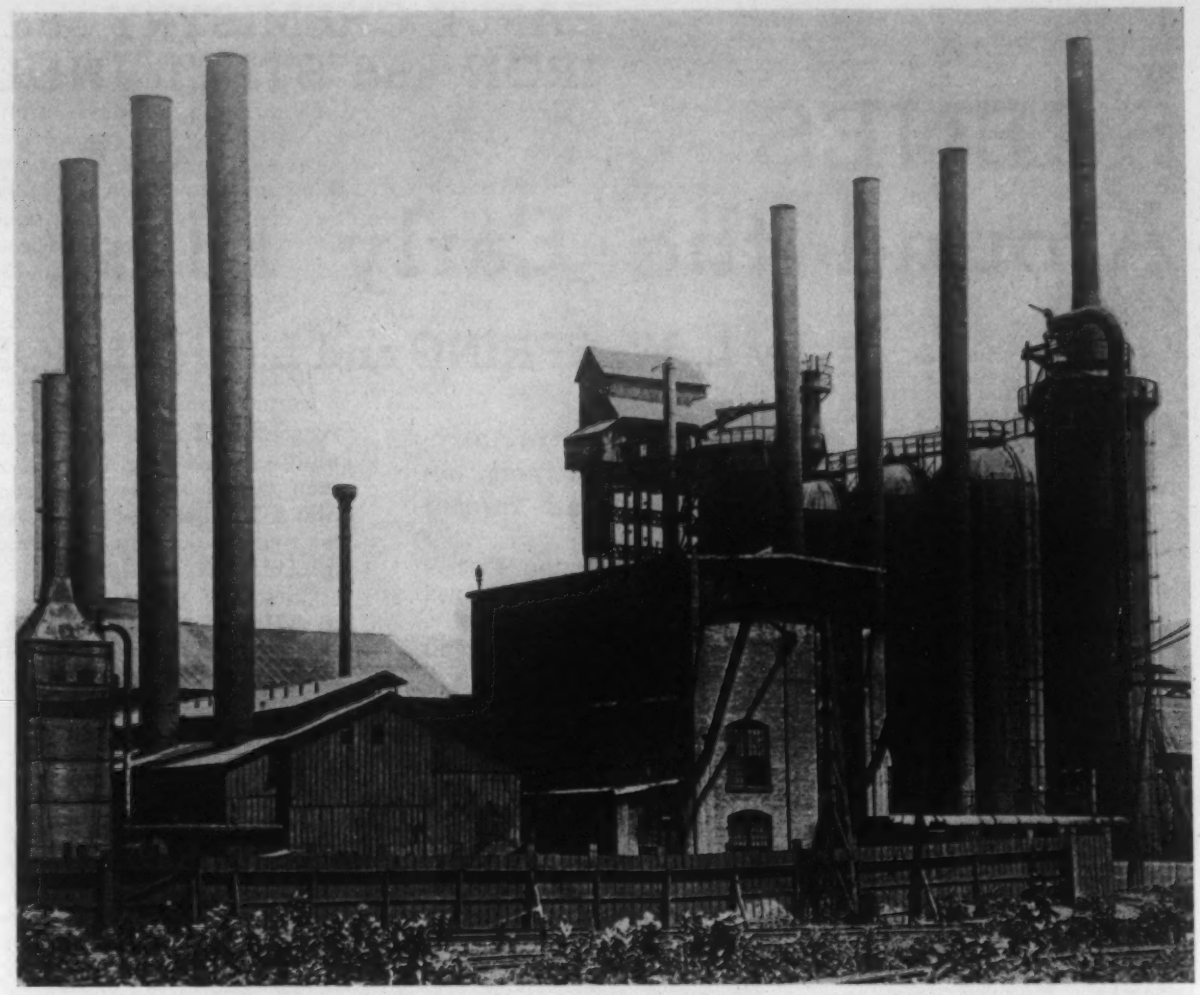
"Material handling was all pick and shovel work and must have cost a lot. But the saddest part of this tale is yet to come. You should have seen the laboratory. The building was all right but in the center was a big brick stack about thirty inches square on top and perhaps eight feet at the bottom. It contained ovens but whether it was their intention to make assays or to cook a veal pot pie for the whole force just as they are always doing in the old English novels, I never knew. There were two pieces of apparatus there. A balance with knife edges worn out and a patent contraption for making soda water. The other liquid needed to complete the formula (which I am not allowed to mention) was not there and had evidently been used up.

"I never saw Middlesborough, but as described to me it was very similar to the above. I was told the main street was 120 feet wide and the hotel never finished was a copy of one on the Canary Islands, but of this I have no first hand knowledge. The machinery from the old Katahdin charcoal furnace in Maine was brought there but never operated.

"The managers of these early plants were called 'Iron Masters' and that title fitted them well for they attended to finance, sales, technical matters and often administered summary discipline to the men who after pay day were 'flown with insolence and wine' (John Milton did not know of moonshine whiskey). All of these men were strong characters, both

able and determined. Some of them might be described in modern slang as 'hard boiled' but most of them had a decided bent for practical research. What they accomplished is recorded in the Journal of the American Institute of Mining Engineers, the Iron Age, Journal of the Charcoal Iron Makers and other publications. I knew a few of them well, others slightly, and some only by reputation. Their names and faces flash before me on memory's screen, though nearly all of them have long since 'struck the long trail of kingdom come!'

"At Longdale, Va., near Clifton Forge, lived Col. J. E. Johnson, for many years manager of the Longdale Iron Co. Closely associated with him were two brothers, Frank and Harry Firmstone. One of them lived at Longdale and the other near Easton, Pennsylvania, from whence they came. You will find these names many times in records of that period. Col. Johnson left two sons, both well-known furnace men. The elder, Guy Roche, during his short career held many good positions as furnace manager at large plants. The younger brother, J. Esrey, was better known owing to his writings and book on furnace practice, theory of critical temperatures, etc. At one time he managed a charcoal furnace (Ashland, I think) and later opened a consulting office in New York. He was killed a few years ago by an auto which skidded and hit him while walking on the sidewalk.



Blast Furnace and Stoves of A. M. Byers Company at Girard, Ohio. Built 1866, dismantled and scrapped 1930.

"Another name not usually connected with the iron trade was that of Thomas C. Platt who was U. S. Senator from New York with Roscoe Conkling. He was known as 'me too' Platt and had large interests in the Tennessee Coal & Iron Co. which was at that time making pig iron and coke with large plants and mines in Tennessee and Alabama. Mr. Platt's activities were in the financial side of the business. If anyone thinks we have a lot of politics now they should have known this period. This was the time when Blaine called Conkling a 'turkey gobbler.' This tactless statement did not help Blaine when he ran for President in 1884.

"Others prominent at this period were B. F. Fackenthal, of the Thomas Iron Co. in the Lehigh Valley; Edgar S. Cook, a progressive furnace man who managed the Warwick furnace at Pottstown, Pa.; S. B. Patterson, who was manager of the Andover furnace at Phillipsburg, N. J., and many others whom I did not know. In Cleveland, Ohio, Marcus A. Hanna was very active in the Lake ore and pig iron trade. He later became very prominent politically in the 1896 campaign.

"We now return to Cincinnati where there were two prominent firms. Rogers Brown & Co., then recently started, who later had large interests at Buffalo, and Matthew Addy & Co. Mr. Addy took an active part in the technical management of the pipe plant which was named after him. I must pause at this point to explain that at this time there was still much poetic sentiment in the iron trade. The blast furnaces were named. Alice, Mary and Helen were well-known and if I recall correctly there were two Ensleys, Lady E and Hattie. Then there was Rising Fawn in Georgia. Blowing in a furnace was something of a ceremony as the torch was applied by the wife or daughter of some officer of the company.

"In some ways things have not changed any. The old timers did many funny things. In one case a furnace using magnetite with a calcite gangue got a pasty slag and added lime to correct the trouble. In Virginia in the early days they found a deposit in downcomer and flues. They did not know what it was but were sure it was not pig iron so they put it on the slag dump until some one found it was nearly pure zinc oxide. In another plant, which for years had used magnetite containing

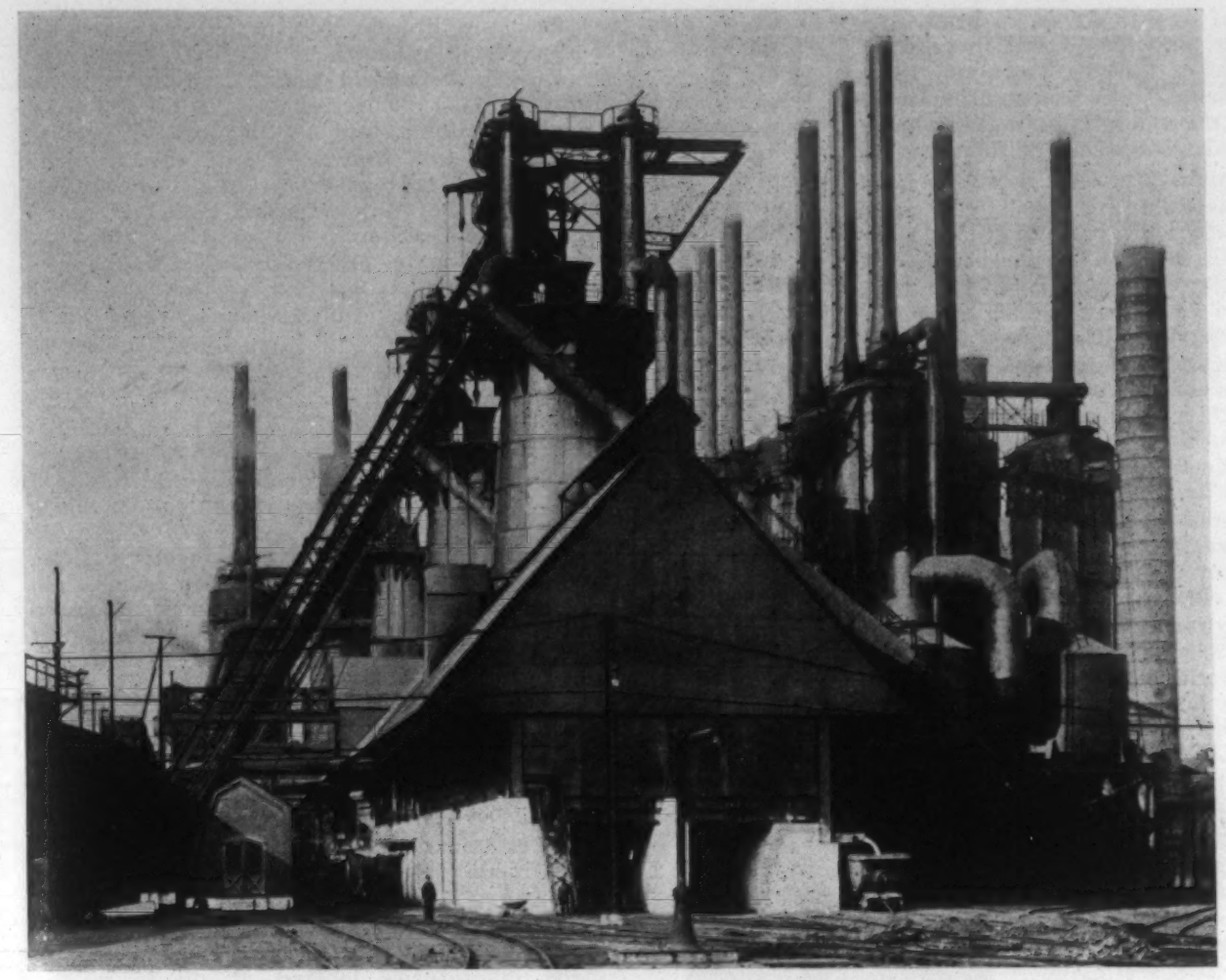
Chemists Who Analyzed Ores	Addresses*	No. of Analysis
Prof. Oscar D. Allen	New Haven, Connecticut	17
Prof. Geo. J. Brush	New Haven, Connecticut	1
J. Blodgett Britton	Philadelphia, Pennsylvania.	56
A. A. Blair	St. Louis, Missouri	2
Dr. C. F. Chandler	School of Mines, New York.	8
Dr. C. F. Chandler & F. A. Cairns	School of Mines, New York.	12
Chandler & Sweitzer		1
F. H. Emmerton	Chicago, Illinois	1
F. B. Jenney	Marquette, Michigan	8
Prof. Geo. W. Maynard	New York	5
Maynard & Wendel		3
Ed. R. Taylor	Cleveland, Ohio	14
Dr. A. Wendel	Troy, N. Y.	20
Dr. Otto Wuth	Pittsburgh, Pennsylvania	30
Samuel Peters		1
T. G. Wormley	Columbus, Ohio	4

*Addresses as printed in 1873, Geological Survey of Michigan.

titanic acid, there was an old foreman who had only recently heard there was such a compound. The next time his beloved furnace got a fit of indigestion the old chap came boiling into the office with some very forceful language about that 'damned botanic acid.'

"There is much data like that I have given you. Mr. John Birkinbine who was for many years a well-known engineer here was very closely connected with the early blast furnaces and has many records of the early charcoal furnaces. He is dead, but his son, John L. W. Birkinbine, has offices in the Commercial Trust Building here and no doubt has the old records. Dr. George H. Meeker of the University of Pennsylvania Medical Laboratory as a young man was chemist at both Andover and Longdale furnaces and probably knew some of the men here mentioned better than I did. Mr. Edward K. Landis (University of Pa. I think) was chemist at the Tilly Foster and Croton mines about 1880. One or both of these mines are now under water, being taken by New York City for water works. Mr. Landis was later with the Pottstown I. & S. Co. which had a basic Bessemer plant at Stowe near Pottstown, Pa. This was one of the very few* plants of that kind built in this country. Mr. Landis had a laboratory on 4th Street below Walnut Street, Philadelphia, for many years. He died about twenty years ago. Thomas M. Drown (Later President of Lehigh

*Probably only two ever built in the United States and neither successfully operated owing to our comparatively low phosphorus iron ores.



Blast Furnaces at Bethlehem, Pa., Plant of Bethlehem Steel Company.

University) had a laboratory on Girard Street, Phila., very early, but I do not know the date. His methods for silicon and phosphorus are still in use.

"I trust you may be able to use some of this material and possibly also get a smile from these stories. We all need something of the kind during these very trying times. I have had to rely on memory but I do not think I have made any serious errors in facts."

In the Geological Survey of Michigan 1869-1873 Volume 1, Page 283, is given a list of sixteen chemists or firms who analyzed ore samples for the Geological Survey. They probably are a representative list of chemists in the United States at that time, prepared to make authoritative iron ore analyses.

The Durham Iron Works at Riegelsville, Penna., had their first chemist as early as 1870. Solomon Sjoberg was brought from Sweden to America by Cooper & Hewitt to erect a Swedish ore roasting kiln at Ringwood, N. J. He was transferred to Durham and opened a laboratory there Oct. 4, 1870. Prior to that time the work for Durham was done mostly by Prof. George W. Maynard of Troy, N. Y. (now deceased).

Cooper & Hewitt, Durham Iron Works, Riegelsville, Pa.

Solomon Sjoberg, 1870-1873.
B. F. Fackenthal, Jr., 1875-1880 (later president of the Thomas Iron Co.).
Baron Carl O. Lagerfell, 1880-1881.
George Aerchy, 1881-1886 (later chemist Disston Saw Works).
William H. Blaueret, 1886-1887 (later with Semet Solvay Co.).
Lee S. Clymer, 1887-1890.
Harvey F. Ruth, 1879-1904.

Dr. Porter W. Shimer was the first chemist for the Thomas Iron Co. The chief chemists for the Thomas Iron Co. beginning in 1878 were:

Thomas Iron Co.

Porter W. Shimer, 1878-1879.
E. J. Schmitz, 1879-1880.
J. E. Fillsbrown, 1880-1881.
R. P. Patterson, 1881-1884.
C. C. Jones, 1885-1892.
Walter Wyckoff, Lehigh Univ., 1892-1926.

Some of the early chemists of the Iroquois Iron Co., Chicago, were as follows:

Iroquois Iron Co., Chicago

Wm. Chamberlain, 1887-1897.
Frank Abbott, 1898-1899.
Fred A. Snow, 1900-1912.
N. H. Bonts, 1912-1917.
J. Ryan, 1917-.....

One of the first chemists in the Ishpeming and Marquette mining districts of which we have record was James E. Jopling. Below is a list of other early chemists in this region:

Ishpeming and Marquette Mining Districts

James E. Jopling, Cleveland Cliffs Iron Co., Ishpeming, 1881, Chief Mining Engineer and Consulting Engineer 1895- to date.
F. J. Baker, Cleveland Cliffs Iron Co., Ishpeming, 1895-1930.
Dr. E. J. Hudson, Cleveland Cliffs Iron Co., Marquette, 1899, Chemist to Manager.
Dr. C. E. Wright, State Geologist, Ishpeming, 1881-1888.
Prof. A. L. Seaman, With State Geologist around 1885, later at Michigan School of Mines, Houghton, Mich.
Rattle, Nye and Mintz, Ishpeming, 1888-1894.
Len Johnson, Rattle, Nye and Mintz, 1888, now Chemist for the Oliver Mining Co.
Robert H. Taylor, Jackson Mine Concentrator, 1881-1884, now U. S. Customs, Sault Ste. Marie, Mich.
E. Z. Burns, Lake Angeline Mine, Jones and Laughlin, 1887.
E. F. Bradt, Lake Angeline Mine, Jones and Laughlin, 1888-1905.

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READERS' COMMENTS

Editor, Metals & Alloys

In compliance with your request I hand you herewith a true account of the early iron industry in Virginia, when the chemist succeeded the iron grader as inspector, consultant, analyst, and scientific information bureau at blast furnace plants. I am delighted that you are publishing a series of articles on the subject, it is a fascinating field, and a worthy cause, so few of us old timers are still in the business. I have had my hand on casseroles, permanganate burettes and platinum crucibles in the service of industry and the Federal government, for many years, but the old blast furnace life still fascinates me, when I recall those old days.

It is a pleasure to relate these happenings, and I await the publication of the remainder of the series of articles, with the greatest interest, I can assure you.

Yours very truly,

RANDOLPH BOLLING

Chemist
Norfolk Navy Yard,
Feb. 27, 1933

THE GREAT industrial boom of the early 90's resulted in the erection of many new blast furnace plants at Bristol, Pulaski, Max Meadow, Salem, Roanoke, Buena Vista, Goshen, Low Moor, and Iron Gate, Va. These plants were well equipped and contained the latest in metallurgical equipment. Most of these stacks were from 70 to 80 feet high, closed with a single bell and hopper, overhead flues and dust catchers, large cast houses for casting foundry iron, and were served with reciprocating steam driven, blowing engines, built by Weimer, or by Southwark Foundry Co. of Philadelphia. The blast pressure was from 7 to 10 lbs., and the boilers were of a variety of

types, some merely large horizontal steel tanks set in brick furnaces fired by blast furnace gases, or with two or more flues of large diameter. Towards the end of this decade, about 1898, vertical water tube boilers of Cahall make, and other well known makers gradually replaced the older types, making more steam and excluding the use of coal to supplement the gases.

Stoves were generally either a plain Whitwell, or Cooper, or combination with either 2 or 4 passes, and 4 stoves were used on each furnace alternately, changing every hour, blast temperatures from 700° to 1100° F. With these furnaces the output was from 70 to 125 tons of pig iron per diem. The handling of slag was done by quite a variety of cinder cars, the old Modoc type, that resembled a coffin, lined with firebrick and mounted on single wheel trucks, to more improved cars, which could be pushed out on the dump by the furnace locomotive, and tilted on the end. All types had a sad habit of jumping the track. The charging of these furnaces was an expensive and laborious process, a stock house gang of about 20 negroes would shovel ore, flux, fork coke, into steel buggies, or very large wheel barrows, these would be rolled to the elevator platform after weighing at the charging scales, and sent up a vertical elevator, at the furnace top were stationed two men who would roll the buggies off the elevator and dump them around the hopper, and send them down again. These men after a charge was landed on the bell would lower it and close it again. The steam engines used to hoist these elevators gave some trouble from the hard usage they received.

These early plants were usually located on a spur track from a main line of railroad, either N & W or C & O, and were surrounded by numerous out buildings for storage of materials, commissary store, Doctor's office, laboratory, and in some cases a village was built to house the men. The Blue Ridge and Allegheny mountains of Virginia made a beautiful setting for these plants, and the mountain air made for virility and activity of the men.

As I was a young man, just out of the University of Virginia, I was sent to the headquarters of the Virginia Iron Coal & Coke Co., at Bristol, Va.-Tenn. This was a large new 20 million dollar corporation which was promoted by Mr. Geo. L. Carter of Hillsville, Va. The general laboratory at the Bristol furnace was a training school for us young chemists, and was in charge of Mr. W. Walley Davis, an old time iron chemist, who was many years chemist for the Crozer Iron Co. of Roanoke, Va. Among the young chemists I found one class mate, Mr. Thurmer Hoggard of Norfolk, Va., and there were others, Mr. James Painter, Mr. J. M. Wilson, and a few more. On my arrival, and reporting for duty, I was quite amazed at the extent and activity of the laboratory, it consisted of several rooms, each containing a large fume hood, with sliding windows and inside were cast iron hot plates heated by large Fletcher gas burners, copper water baths, steaming with casseroles, beakers, and Erlenmeyer flasks, which contained silicon determinations, phosphorus, and manganese determinations, and a large number of iron ores in small beakers, all either containing boiling hydrochloric or dilute acids.

The walls of the laboratory were lined with long chemical desks, with soap stone and wood tops, with cupboards and drawers below, for storage of rubber stoppers, filter paper, beakers and glassware. On the desk tops were long rows of filter stands, all carrying glass funnels, rows of flasks with solutions being reduced with zinc for the old time titration with permanganate, for phosphorus. Long rows of suction flasks connected up with rubber tubing, to Richards water blast suction pumps, the funnels carrying platinum cones. Chemists were filtering off silica and graphite from pig iron, for silicon determinations, and acid and hot water washing bottles were active in washing the precipitates. At other desks a set up of evolution flasks carried thistle tubes, and a pipette bend, connected with an absorption gas washing bottle, containing ammoniacal cadmium chloride, were bubbling merrily as the borings dissolved in hydrochloric acid, in the famous evolution method for sulphur in pig iron. Over at other desks iron ore solutions were being titrated with bichromate, for total iron, touching on porcelain tile with ferricyanide indicator, and in another room were set up the carbon combustion furnaces, each with its absorption and purifying train. Platinum combustion tubes were used and the carbon in pig iron after separation of the iron by acid ammonium copper chloride solution was filtered off on platinum boats with perforated bottoms, using asbestos filter bed. A large balance room in which also the office and library was located, adjoined the laboratories. A convenient arrangement of sinks, compressed air for blast lamps, and overhead shelves holding standard solutions to supply automatic burettes for general titrations. Located in adjoining building was an ore crusher, bucking boards, sampling tables, cast iron and agate mortars, drill press, and also a gasolene gas generator of homemade construction to supply the laboratory with fuel gas. This generator consisted of a large 110 gallon tank containing baffles and air from the cold blast main piped to the tank, bubbled through the highly volatile gas machine gasolene used and furnished a good supply of gas, fully equal to ordinary city gas.

Randolph Bolling

The Bristol laboratory besides being a finishing school for metallurgical chemists was called upon to report on all prospecting work in the different ore fields in Va., Tenn., and Ky. Blast furnace chemists at different plants of the company also forwarded their samples of iron, ores, slag, coke, and limestone, in order that occasional check analyses might be run to determine the accuracy of their work.

Mr. W. Walley Davis was a graduate of Lafayette College, and had been appointed chemist for the Crozer Iron Co. in 1890, whose twin furnace plant was located just east of Roanoke, Va., on the main line of the Norfolk & Western Railway. He was appointed in 1890 and the company being a well managed and prosperous blast furnace concern, had fitted up a very well equipped chemical laboratory, on the second floor of their office building. The writer who was transferred there in 1902 can testify to the well arranged laboratory, chemical fume hoods, work benches, balance room, sinks, and ore sampling room. The laboratory was supplied with gasolene gas from a Detroit gas making machine. These machines were standard equipment for blast furnace laboratories located at plants in the mountains, and were very efficient, they operated on the principle of blowing air from a weight driver blower through a tank sunk in the ground, which contained a large surface of sheet metal baffles to vaporize the gas. As this was before the day of the automobile the refiners sold this very cheap, about 7 cents per gallon and it was about the equivalent of modern aviation gasolene, it worked very well, and as all our operations depended so much on gas heating, it was a most important part of our equipment.

Mr. Davis was a chemist of the old school, the day before standard samples were put out by the Bureau of Standards or the American Foundrymen's Association, who were the pioneers in the pig iron standards. He had worked alone at Crozer, his only assistant being a young man without technical training, a Mr. Douglas, who prepared the drillings from sample pig irons, as cast at the furnaces, and who sampled the slags and furnace stock of raw materials. There were a few others of the first blast furnace chemists still working, from the decade beginning in 1890, a Mr. McGavock, was chemist at the Pulaski Iron Co's furnace at Pulaski, Va. Then there was Jerome Keeley, Jr., a young University of Pennsylvania graduate who was chemist at Crozer from 1894 to 1899. I knew him very well and thought he was a very intelligent man well educated, and devoted to iron chemistry.

At Buena Vista furnace, built in 1890 there was quite a large turn over in chemists, the first chemist was a Pittsburgh man, a Mr. McDonald who was in charge in 1890, and later a Mr. Sample from Richmond, Va., in 1894.

At the Goshen furnace of the Allegheny Ore & Iron Co., the laboratory was built in 1889 when the plant was built by an English company, later the plant changed hands and was operated by the Empire Steel & Iron Co., and at the time I was Superintendent, 1902-1903 it was owned by the Allegheny Ore & Iron Co. of Clifton Forge, Va.

The Iron Gate furnace near Clifton Forge, Va., was built about 1889 and the first chemist was Mr. W. W. Taylor, a graduate of Ann Arbor University who I knew quite well, he was in charge 1890 to 1895 and afterwards was made superintendent, as many of the first blast furnace chemists in Virginia and neighboring states were. Chemists took keen interest in the metallurgical operations and with their technical knowledge soon were promoted to higher posts. At Middlebore, Kentucky, a large open hearth steel plant and blast furnaces (2) were built by an English company in 1890, they had a very large and extensive laboratory, and brought British chemists over to man the laboratory. At Johnson City a blast furnace operating on

(Continued on Page 74)

B. A. Rogers

MAGNETIC PROPERTIES OF IRON-COBALT-TUNGSTEN ALLOYS

By B. A. ROGERS*

SOME years ago, the author was concerned with an investigation of the magnetic and mechanical hardness of a number of dispersion hardening binary and ternary iron alloys.[1] The results of the study were interesting since they showed that high coercive forces, as well as great mechanical hardness, were obtainable in carbon-free alloys. An additional matter of interest was the considerable number of cases in which there appeared to be no evidence of the correlation of these properties which is so prominent among the magnet steels.[2] That such a relation is not fundamental has been noted by other observers.[3]

The most striking behavior was exhibited by ternary alloys of iron, cobalt, and tungsten and also by alloys of iron, cobalt, and molybdenum. For the compositions investigated, it was found that not only did the coercive force not increase simultaneously with the mechanical hardness but actually attained a minimum value under the same heat treatment which yielded approximately maximum hardness.

Such behavior seemed sufficiently interesting to warrant a new investigation covering a wider range of compositions and involving the measurement of additional properties. There also appeared the possibility, somewhat remote it must be admitted, that new light might be thrown on the origin of coercive force changes. The iron-cobalt-tungsten group was selected as the subject of the new research and a series of alloys with the intended compositions shown in Fig. 1 was prepared. Such intervals between compositions leave much to be desired as to completeness but the labor of studying the 20 alloys selected proved to be considerable.

While the new work was in progress, the results of a valuable investigation of the constitutional diagram of the iron-cobalt-tungsten system were published by Köster and Tonn.[4] Later, there appeared a second publication by Köster[5] in which was included a discussion of the magnetic properties of compositions corresponding roughly to Groups 1 and 2 of this report. In general, the 2 accounts agree, though not in every particular as a study of the details will reveal.

PREPARATION OF THE ALLOYS

In preparing the alloys, materials of high purity were selected. The tungsten was wire scrap from a manufacturing process. Both the iron and cobalt were electrolytically refined. An idea of the total amount of impurities may be obtained from the analysis of alloy No. 14 which contained: 0.02% C, about 0.01% Mn, 0.004% P, 0.009% S, 0.03% Si, trace Ni, trace Cu, 9.91% W and 61.09% Co.

Melting was carried out with an Ajax-Northrup high frequency furnace. The 600 g. charge was placed within a silica tube in which the maximum pressure occurring during melting was of the order of 1 mm., except that in 2 cases, the pressure did rise to 3 mm. The crucibles were made of electrically fused magnesia without the addition of a binding material. This entire procedure is commonly used and need not be described further. It might be added that it is not easy to make small ingots, which contain tungsten, perfectly homogeneous, particularly if cobalt is a major constituent. Sykes[6] has observed this difficulty in preparing cobalt-tungsten alloys by melting.

Previous experience had indicated that about the only forging operation which could be carried out successfully on some of the compositions was a simple flattening to an oval slab at a temperature not much below the melting point. All of the ingots were, therefore, flattened to slabs about ⅜ in. thick by 4 in. long.

PREPARATION AND HEAT TREATMENT OF TEST SAMPLES

From each of these blanks, 2 bars roughly ⅜ in. wide were cut with a thin rubber cutting wheel. These were then quenched in water after being subjected to a temperature of 1400°-1450° C. for ½ hour. The longer and more satisfactory bar, i. e., the one which had been taken from along the axis of the blank, was turned or ground to a round rod 8 cm. long by 0.793 cm. in diameter.† The other of the pair was cut into smaller pieces for determinations of density and hardness.

In carrying out the aging treatments, it would have been desirable to have used a different sample for each temperature, but as this would have required the preparation of a prohibitive number of specimens, the pieces described above were annealed at successively higher temperatures. Five-hour annealing periods were employed for all treatments from 370° to 1050° C. At 1135° and 1250° C., the length of time was reduced to 3 hours and 1½ hours respectively. In all cases, the samples were surrounded by an atmosphere of hydrogen and were allowed to cool in the furnace. Only the more interesting samples were treated at 1135° and 1250° C.

Up to 1050° C. the treatments were performed in a silica tube which passed through a Nichrome wound tubular furnace. At 1135° and 1250° C., the aging was done in a molybdenum wound furnace inclosed in a tight water-jacketed brass cylinder through which a stream of hydrogen was maintained.

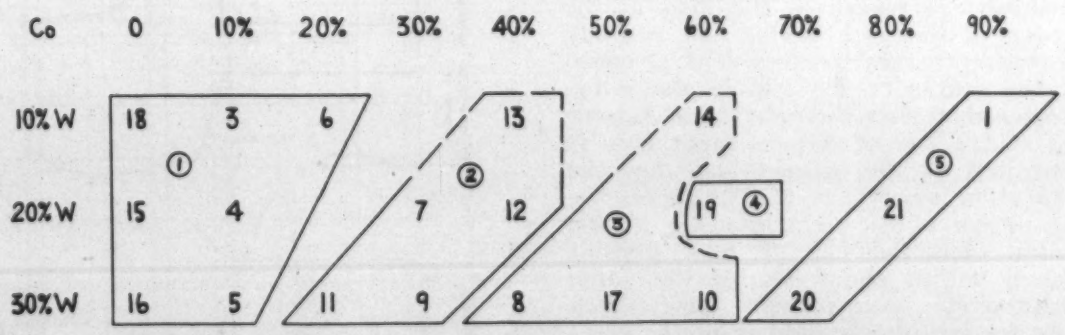

Fig. 1. This chart shows the number and intended composition of the alloys prepared. They are grouped according to behavior. The number in the circle is the number of the group.

PHYSICAL APPARATUS AND MEASUREMENTS

The physical characteristics of the samples were determined after quenching and also after each aging treatment. Usually the following 7 properties were measured:

1. Coercive force
2. Residual magnetism
3. Flux density in a field of 17,200 oersteds** (practically saturation)
4. Density

*Research Laboratory of Physics and Cruft Laboratory, Harvard University.

†No. 5 broke into a number of pieces. It appeared to have been badly cracked in forging or quenching. Qualitative values of coercive force and residual magnetism were obtained by using two pieces.

**The use of oersted as the unit of intensity of magnetic field has been approved by the American Institute of Electrical Engineers and other bodies. The author prefers the term above either gauss or gilberts per centimeter.

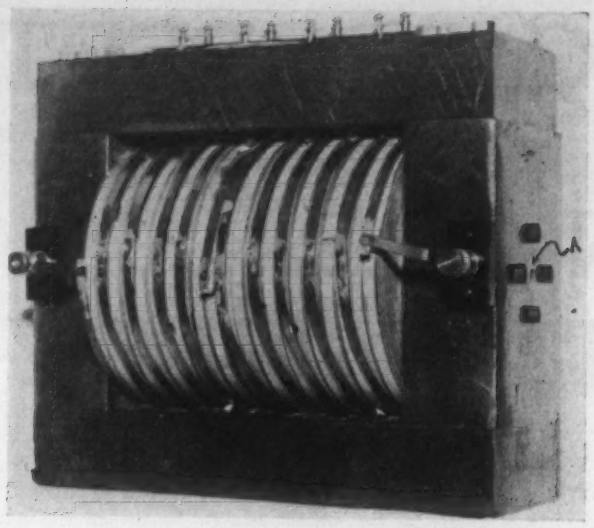

Fig. 2. The electromagnet used in finding the flux density at H = 17,200 oersteds. A indicates the hole in which the samples were inserted.

5. Electrical conductivity
6. Hardness
7. Young's modulus (dynamic value)

Only a brief description of the equipment used in making these measurements will be undertaken.

Coercive force and residual magnetism were measured on a yoke apparatus which was essentially a Fischer[7] comparator. The instrument available had been made for bars longer than those to be tested and the gap was, therefore, shortened by the addition of Armco Ingot Iron slabs which were fitted on accurately by scraping. The calibration of the comparator was effected by observing the deflections obtained when making measurements upon a set of longer test bars whose properties had been determined by a J permeameter.[8] Down to coercive forces of about 20 oersteds, the calibration is satisfactory but the accuracy decreases for lower values. For the comparative results of this investigation, the measurements of coercive force are sufficiently accurate. Values of residual magnetism are likely to be in error by 300 or 400 gauss. Both coercive force and residual magnetism are from a maximum field of about 1500 oersteds.

The flux density at H = 17,200 oersteds was measured with the electromagnet shown in Fig. 2. This magnet is a modified form of the one described by Stäblein and Schroeter[9] and used later by Maurer and Schroeter[10] in an investigation of the saturation values of steels. Air cooling has been substituted for water cooling and an extra magnetizing coil inserted in the 1.5 cm. gap between the pole faces to compensate for the diminished strength of the field at the center of the gap.[11] This coil actually over-compensates as the field strength at the center of the gap is about 3% greater than near the pole faces. Assuming that a bar of Armco Ingot Iron is saturated by the magnet and that the saturation density is 21,300 gauss, the calculation of the field intensity at the center with the bar of iron present agreed within about 1% of the value with no specimen present. The search coils are completely hidden by the compensating coil but their terminals may be seen on the top of the magnet. The specimens were inserted through the 8 mm. hole A and pushed along until they bridged the gap between the pole pieces. Values of flux density at H = 17,200 oersteds are generally correct within ± 200 gauss.

Density values were measured by the method of immersion in water. In order to secure the greater accuracy necessary for the relatively small changes which occurred, the temperature of the distilled water was measured frequently and a film of olive oil maintained on the surface to destroy surface tension effects. The data for sample No. 9 was secured on the magnetic sample as no extra material was available for density determination. Longitudinal cracks reduced the accuracy somewhat but the general trend is certainly correct.

To get the electrical conductivity, the sample was placed in series with a standard 0.01 ohm resistance. Then with current from a storage battery flowing through the circuit, the potential drops across the sample and the standard resistances were measured alternately with an L & N Type K potentiometer. From the data so obtained the specific resistance in ohms/cm.^{3} was calculated. Finally, the reciprocal of this value, i. e., the conductivity in mhos./cm.^{3} was used to express the characteristics of the specimen. The values given are for a temperature of 25° ± 0.1° C.

Hardness values were measured on a Model 4H Rockwell Hardness Tester. In general, the values obtained are the average of either 2 or 3 impressions taken on surfaces which were cross sections of the original bar cut from the forged blank.

The value of Young's modulus was obtained by using the magnetostriction apparatus of Prof. G. W. Pierce.[12] The underlying idea is to induce the bar to vibrate with its natural frequency by making it part of an electromechanical system and then to measure the rate of oscillation of the circuit. The value of Young's modulus in dynes/cm.^{2} is calculated from the formula

$$E = 4\ l^2\ f^2\ \rho$$

where f is the frequency of vibration, l is the length of the bar in cm., and ρ is the density in g./cc. The value of the modulus so obtained may be readily reduced to lbs./in.^{2} by dividing the corresponding number in dynes/cm.^{2} by 69,000. The modulus of elasticity measured in this way is the dynamic modulus of the material and may differ from the usual static value by 2 or 3%.

DISCUSSION OF RESULTS

If all the details of behavior were considered, it might be said that almost every composition had its own characteristics. However, in observ-

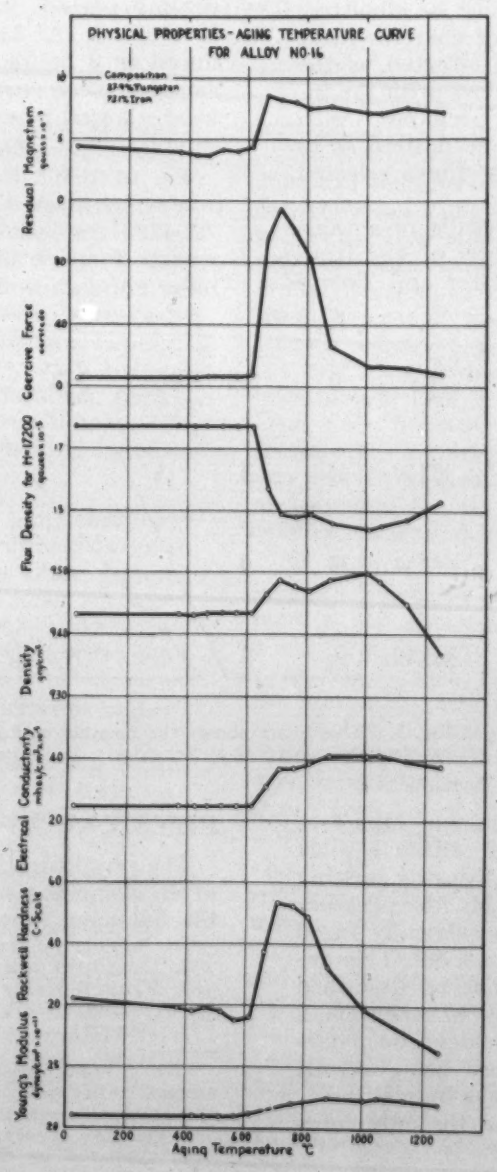

Fig. 3.

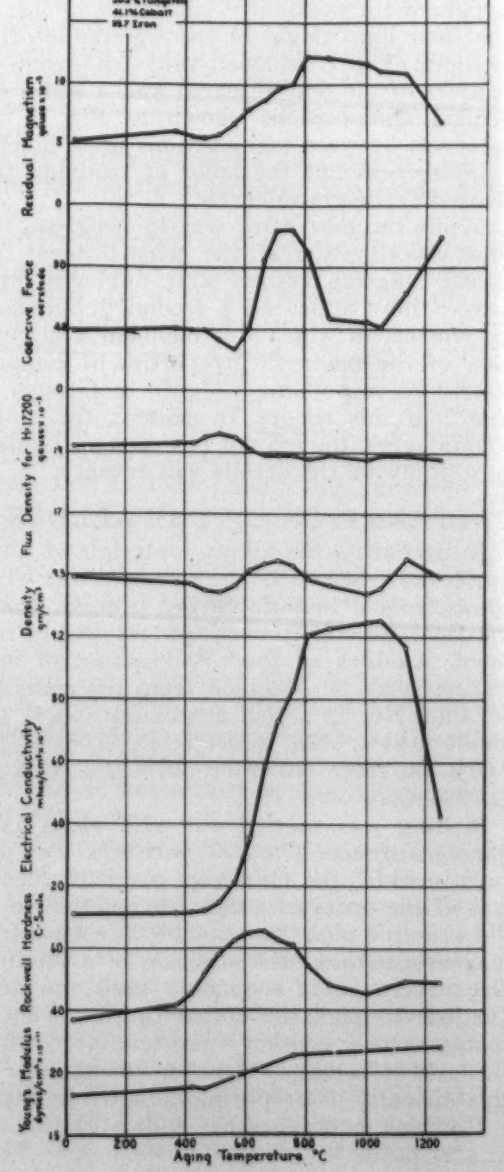

Fig. 4.

ing the larger changes certain similarities are evident. For the purpose of analyzing the results obtained, the alloys may be divided into 5 groups as indicated in Fig. 1 by the closed loops. The dotted part of the loop indicates that the composition so inclosed does not exhibit all of the characteristics of the group but a sufficient number of them to allow its attachment for the sake of convenience.

Group 1 includes those alloys whose behavior follows that of the binary iron-tungsten alloys. Alloy No. 16, containing, by analysis, 27.9% and 72.1% Fe has been selected as a representative of this group and will serve as a basis of discussion. Fig. 3 shows the curves obtained by plotting its various properties as ordinates against aging temperatures as abscissae. The outstanding features of the group may be summarized by the following statements:

1. All properties experience their first marked change after the 665° C. treatment. At this point the saturation decreases and the other properties increase.
2. Hardness and density follow generally similar trends and both decrease markedly after passing their maxima.
3. Young's modulus, for the 3 members of the group on which measurements were made, remained at its increased value.
4. The other properties showed some tendency to return to their initial values after annealing above 1050° C.

In accordance with prevailing theories, so far as these are applicable, the various changes might be explained as follows:

1. The increase in hardness is of the usual normal[13] age hardening or dispersion hardening type in which the increased hardness is considered to arise from a keying action of the precipitated particles in the slip planes.
2. The increase of coercive force is a natural accompaniment of increased hardness and is most probably to be ascribed to the straining of the lattice by the precipitation of compound.
3. The decrease of flux density at H = 17,200 oersteds is caused by the transfer of iron from a magnetic state to a non-magnetic or less magnetic state.
4. An increase in electrical conductivity is a feature of normal hardening and is in agreement with the general fact that a solid solution has the lowest conductivity of any alloy type.
5. If it is assumed that the increase in Young's modulus is caused by the presence of many particles of presumably low compressibility, then the results indicate that the particle size is not critical, or possibly that the value of the modulus is not a function of particle size.

This group then presents nothing contradictory to the accepted ideas of age hardening phenomena. One explanation of the decrease in conductivity and density upon aging above 1050° C. is the resolution of compound.[14] It has also been suggested that the formation of Fe_2W may be exerting an influence here.

Group 2, which is represented by the alloys numbered 12 and 9, displays the trends indicated in Figs. 4 and 5 and summarized below:

1. There is a peculiar drop in coercive force at a comparatively low temperature which reaches its minimum value at about the same point as the maximum hardness reading.
2. A minimum in density occurs at about the same or at a little lower temperature as the minimum in coercive force.
3. A maximum occurs in the curve of saturation in the same region.
4. The increase in electrical conductivity is large. For No. 12, it exceeds 800%.
5. The rise of coercive force from its low temperature minimum begins at about the same temperature at which the electrical conductivity starts to rise rapidly. No. 13, which experiences a minimum in density but not in coercive force, is an exception to this rule.
6. There is a secondary rise in hardness which for No. 13 amounts to about 10 points.
7. Coincident with the secondary rise in hardness, an increase in coercive force takes place.
8. The rise in the value of Young's modulus is generally large. It may amount to as much as 30%.
9. The electrical conductivity and Young's modulus follow generally similar trends.
10. It is probable that a phase of extreme brittleness sets in just as maximum hard-

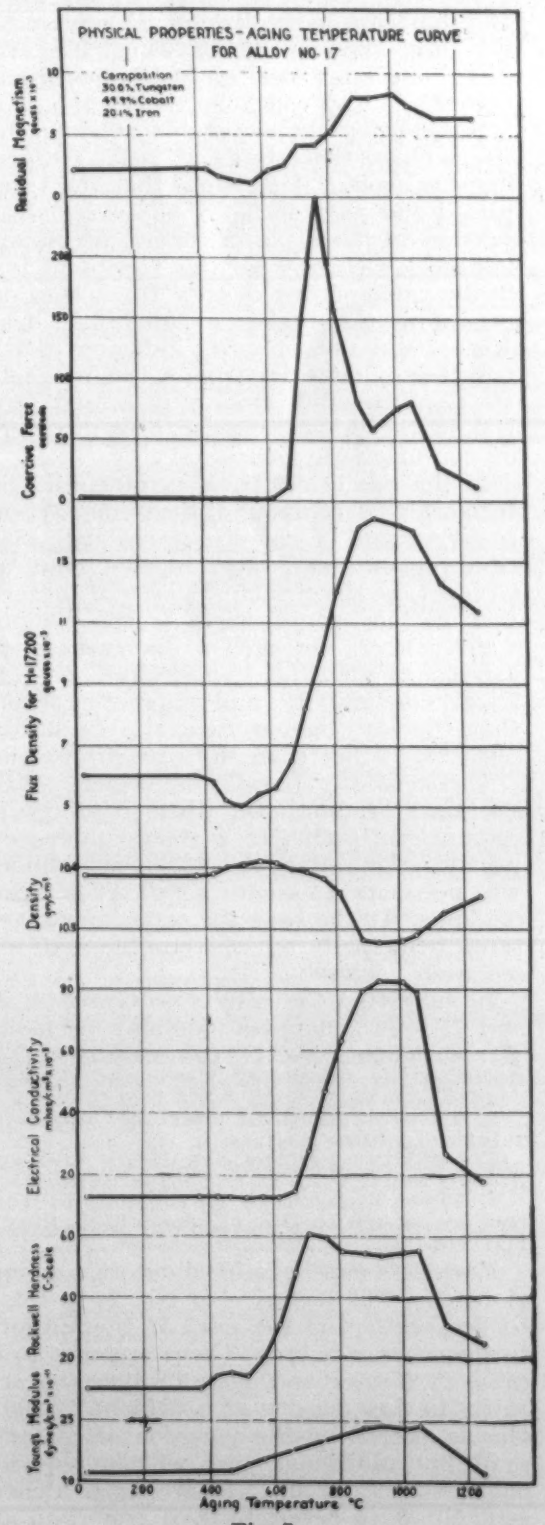

Fig. 5.

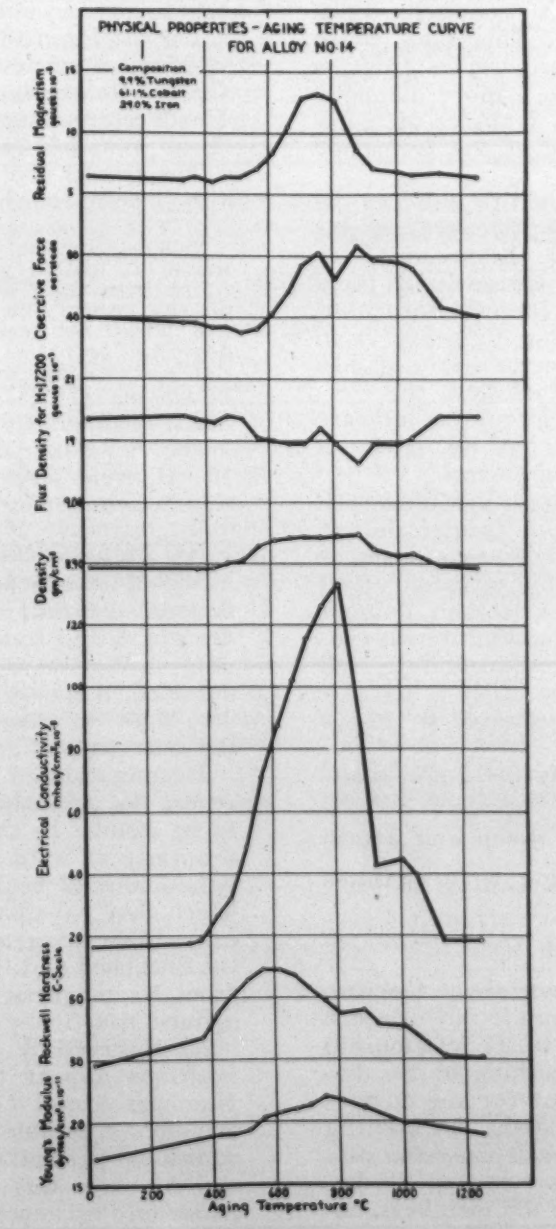

Fig. 6.

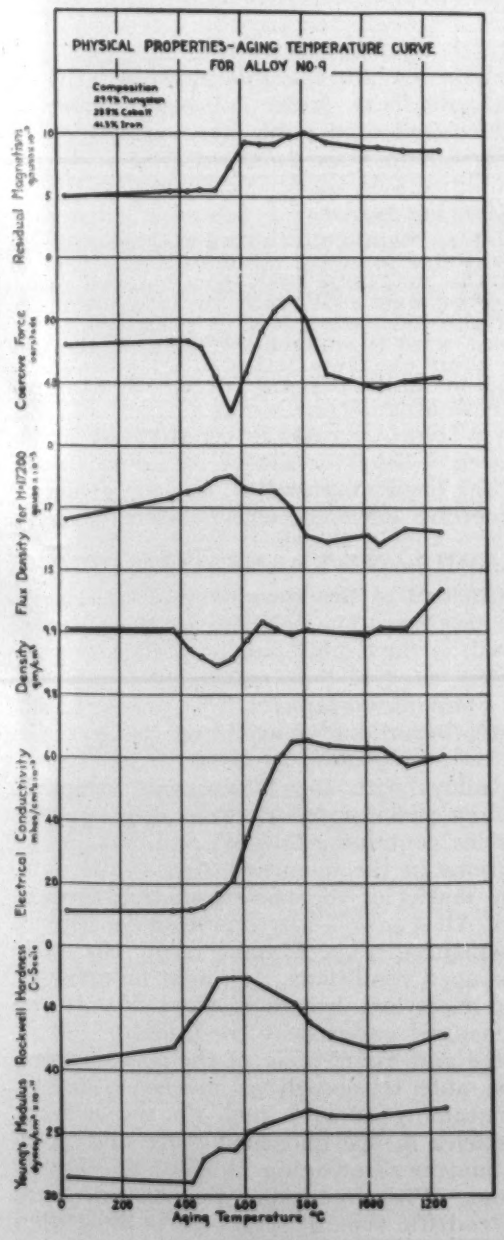

Fig. 7.

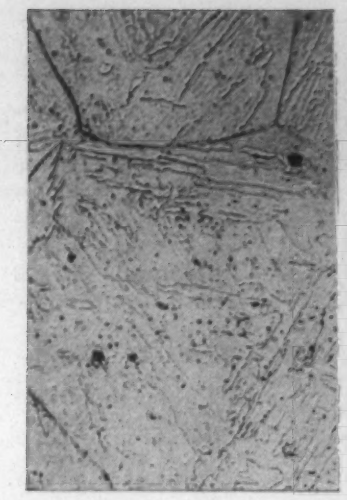

Fig. 8. Alloy No. 12 containing 20.2% W, 41.1% Co, and 38.7% Fe, after quenching. 200 X.

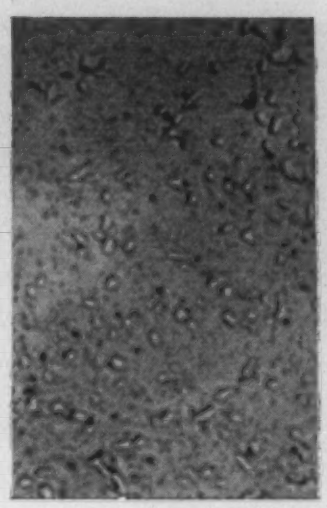

Fig. 9. Alloy No. 12 after aging at 1250° C. 1000 X.

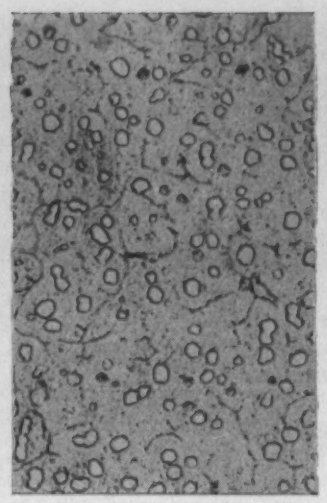

Fig. 10. Alloy No. 11 containing 29.8% W, 21.2% Co, and 49.0% Fe, after quenching. The excess constituent shows that 30 W is not soluble in these alloys. 400 X.

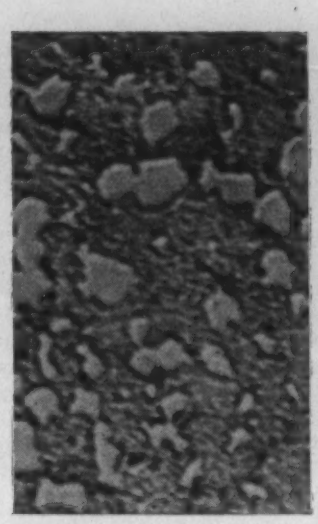

Fig. 11. Alloy No. 11 after aging at 1250° C. Additional precipitate is shown. 1000 X.

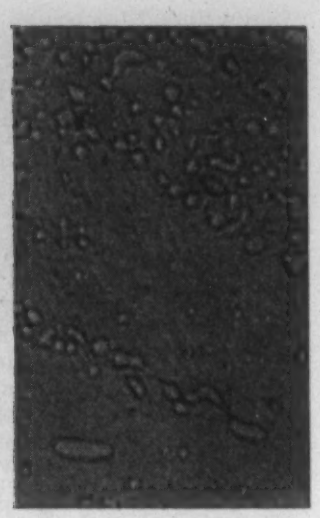

Fig. 12. Alloy No. 9 containing 29.9% W, 28.8% Co, and 41.3% Fe, after aging at 665° C. The quenched specimen is identical in appearance. 600 X.

ness is reached and passes off 50° to 100° C. higher. Composition 7, 9, and 12 all split under the diamond cone at approximately their maximum hardness.

11. All of the members of this group attain high hardness values generally comparable with the hardest steels.

The behavior of the members of this group is more remarkable and also more difficult of explanation than in the preceding case. The explanation which Köster gives of the early rise of hardness is based on the transformation which these alloys experience and which he names the $\alpha - \gamma$ transformation, the γ phase being the one stable at about 1000° C. and higher and the α phase that stable at room temperature. During quenching, the cooling is so rapid that the transformation is not completed and part of the γ phase remains. Upon reheating, conversion to the α phase occurs, accompanied by an increase in hardness. Evidence for this viewpoint is given by the maximum in the value of flux density for a field of 17,200 oersteds which occurs in the region of minimum density. This fact, which Köster did not observe, indicates that there occurs: first, a transfer of material from a less magnetic to a more magnetic state, presumably from γ to α, and second, transfer of material in the opposite sense probably because of the formation of non-magnetic compound.

If the rise in electrical conductivity be taken to indicate the formation of compound, then comparison of the curves of this property and of coercive force suggests that the precipitation of compound may also in this case, as apparently it is in Group 1, be the principal cause of increased coercive force, but that in this group, there is the complicating influence from which arises the earlier decrease in magnetic hardness. In agreement with this hypothesis is the fact that both the electrical conductivity and magnetic saturation curves indicate that the low temperature rise in hardness has its origin in something other than the precipitation of compound.

The generally parallel movement of Young's modulus with electrical conductivity, when readings on the former permit comparison, points to a steady increase in both properties as precipitation advances. It is unfortunate that greater effort was not made to secure a full set of accurate data on Young's modulus. At the time the experiments were made, interest centered principally on whether the material would oscillate well magnetostrictively.

In surveying the results on Group 3, as illustrated by Fig. 6 and 7, four generalizations may be made:

1. Excepting No. 14, the members are relatively non-magnetic in the quenched state but their saturation values increase strongly with heat treatment.
2. The increases in coercive values are sharp and attain relatively high values.
3. Density changes are large and coincide with changes in flux density at H = 17,200 oersteds.
4. There appears to be a tendency for the various properties to return to the values which they had when the material was in the quenched state.

Even less can be said about this group than about the previous one. The inclusion of No. 14 in this group is due as much to desperation on the part of the author as to its relationship to the other members. There appears to be nothing in the diagram of Köster and Tonn[4] which can account for the curious shifts in flux density at a field of 17,200 oersteds. An inviting clue is offered by the γ region of Sykes'[6] cobalt-tungsten diagram but additional work will be required to clear up the behavior of this group. The strong tendency of the members, except No. 8, to revert to their condition after quenching is possibly to be ascribed to an actual quenched condition after annealing at high temperatures. Sykes[6] has pointed out, with respect to the cobalt-tungsten alloys that the precipitation from solution is very slow when cooling and that quenching in water is unnecessary. Measurements on some of the alloys which were re-aged at 760° C. after the 1250° C. run, showed that their hardness, conductivity, and coercive force readings had returned to higher values.

The behavior of No. 8 is disturbing to the idea that the rise of coercive force is caused by the precipitation of compound. This alloy had already attained its maximum coercive force before the conductivity showed an appreciable change. The damaging effect of the exception is somewhat diminished by the associated rise in saturation value which indicates the occurence of some inward disturbance which might require to be taken into account.

Except for moderate changes in electrical conductivity and residual magnetism, alloy No. 19, the sole representative of Group 4, remained almost inert under all heat treatment. Hardness readings, which indicated some inhomogeneity, clustered around B-75 to B-80 with a rise to about B-85 at 810° C.

The results of measurements on Group 5 will be passed over very briefly for the following reasons:

1. The alloys are not as homogeneous as they should be.
2. The compositions were incorrect. Chemical analysis of material milled from the magnetic test bars showed much more iron than was to be expected from an analysis made on the cobalt. Two of the bars were low in tungsten.
3. The heat treatment used in quenching was not the one designed to bring out their characteristics in a proper manner as was discovered in making some further treatments after the 1250° C. annealing.

All members showed a slight decrease in conductivity at the lower aging temperatures, a behavior shared by alloys 10 and 19. All were strongly age hardening and all showed generally simultaneous rises of coercive force and electrical conductivity.

PHOTOMICROGRAPHS AND TRANSFORMATIONS

No effort was made to add to the knowledge of the constitutional diagram of these alloys. The behavior of the alloys of Groups 3 and 4, as well as the additional lines of the binary diagrams given by Sykes suggest that new results might be obtained. A number of photomicrographs will be presented and also data on those transformations which were visible under the microscope.

Examination of the alloys with 10%W does not definitely reveal the presence of any precipitated particles large enough to be visible. In the series containing 20%W, numbers 15 and 4 appear as solid solutions in the quenched state while numbers 7 and 12 bear the marks of the transformation through which they have passed. All 4 reveal a precipitated constituent after high aging temperatures. Figs. 8 and 9 show No. 12 in the quenched and in the aged conditions. As might be expected from its magnetic and electrical behavior, alloy No. 19 remained practically unchanged under heat treatment.

As observed by Köster and Tonn, none of the ternary compositions appear to be able to absorb as much as 30%W. Numbers 5 and 11, containing 10 and 20% Co respectively, exhibited insoluble particles in the quenched state and much additional precipitated matter after aging at 1250° C. Figs. 10 and 11 show this change. With increasing Co content, there comes into existence a dendritic type of structure as illustrated in Fig. 12 which shows No. 9, with 30% Co, after aging at

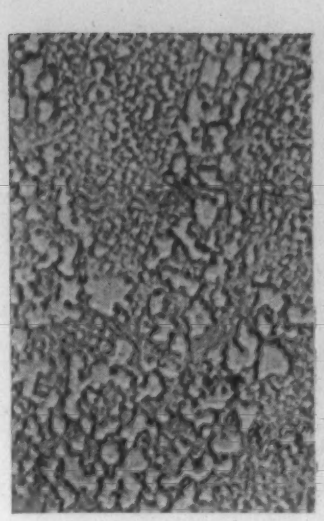

Fig. 13. Alloy No. 9 after aging at 1050° C. Precipitate is appearing over the entire area. 750 X.

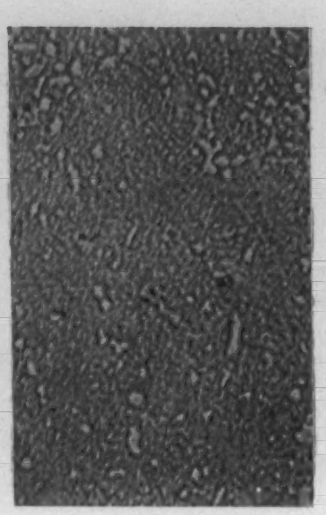

Fig. 14. Alloy No. 8 containing 29.7% W, 40.2% Co, and 30.1% Fe, after aging at 810° C. 600 X.

Fig. 15. Alloy No. 8 after aging at 1250° C. 1000 X.

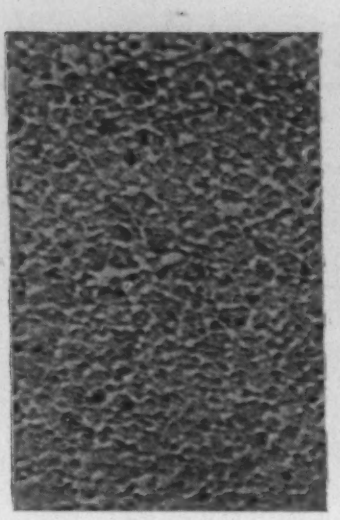

Fig. 16. Alloy No. 17 containing 30.0% W, 49.9% Co, and 20.1% Fe, after aging at 1135° C. 600 X.

Fig. 17. Alloy No. 17 after aging at 1250° C. 1500 X.

665° C. It has attained its maximum hardness but its appearance is the same as in the quenched condition. Fig. 13 shows the same sample after treatment at 1050° C. Precipitate is appearing both in the dentrites and in the filler. Further aging at 1250° C. produced little change except possibly to increase the size of the precipitated particles.

The appearance of alloy No. 8, which showed markedly different properties from No. 9, appears so much like it in the quenched state that Fig. 12 could also serve to represent it. As shown in Fig. 14, a precipitate is already appearing at 810° C. This composition changed little upon heating at 1050° C. but Fig. 15 shows that after 1250° C. a totally different appearance, indicating the presence of 3 phases, has come over it. Alloy No. 17, which shows less inter-dendritic material than No. 8 while in the quenched state, also exhibits a marked change at higher temperatures as can be seen in Figs. 16 and 17. Alloy No. 10 does not develop a third phase but does show twinning faintly, as does also No. 17 in the quenched state.

The allotropic changes as revealed under the microscope[15] are summarized in Table I. The temperatures stated are not exact. Changes in appearance were often gradual, and furthermore, a sample coming up from the quenched state for the first time generally showed signs of transformation at a lower temperature than did a specimen which had been previously annealed at 1250° C.

Changes in trends occur in the region of transformation in alloys Nos. 13 and 14 but not for the others.

CONCLUSIONS

The hope of finding an explanation of the origin of coercive force changes has not been fully realized. It has already been pointed out by Köster,[3] that in the case of Fe-C and Fe-N the size of the precipitated particle is related to the magnetic properties, but the present case is complicated by the fact that the point where precipitation begins is not known. A reasonable assumption is that it begins where the electrical conductivity starts to increase. If this assumption is made, then the results of this investigation do suggest that the increase of coercive force depends upon the initiation and development of compound from a supersaturated solid solution, but at least 2 exceptions remain for which no definite explanation can be offered. In this connection it seems desirable to investigate thoroughly the binary Fe-Be and Fe-Ti alloys, both of which show an increase in hardness before any change in coercive force is manifested.[1]

Regardless of the indefiniteness indicated in the previous paragraph, certain results are of interest:

1. The increase of conductivity obtainable by heat treatment is much greater than for any other alloy yet examined. This increase may amount to as much as 800%.
2. Coercive forces practically equal to those of cobalt magnet steel have been found. Unfortunately the associated values of residual magnetism are too low to make the materials of practical interest.
3. Another alloy has been added to the list of those which can be made feebly or strongly magnetic at will.
4. So far as the results on a single composition can indicate, the dynamic Young's modulus is independent of the size of the precipitated particles.
5. In most cases, the electrical conductivity and Young's modulus attain their maximum values simultaneously, presumably when complete precipitation has been accomplished

TABLE I.

Alloy No.	Temp. of Transformation	Type of Transformation
3	975° C.	iron
6	950	iron
7	785	faint cobalt
12	690	cobalt
13	800	very faint cobalt
	925	strong iron
14	840	

ACKNOWLEDGMENTS

The author is indebted to a large number of people. Grateful acknowledgement is made to Profs. P. W. Bridgman and E. Leon Chaffee for supervising work outside their fields of greatest interest. Prof. Sauveur, Dr. L. R. van Wert, and all other members of the Department of Metallurgy have extended the use of the facilities of that department and in addition have bestowed numerous favors. Dr. J. M. Ide granted the use of the magnetostriction equipment on which his own investigations are being carried out and gave instructions for its use. I am indebted to Messrs. Debes and Staples at Northeastern University for the comparator, and to Mr. K. L. Scott for the measurements necessary to its calibration. The care with which the chemical analysis has been carried out by Mr. W. M. Saunders is also much appreciated.

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Readers' Comments

(Continued from Page 68)

low phosphorus ores from Elizabethton, Tenn., made the only low phosphorus iron in this section, the first chemist was a Mr. Carter, who had been in this line of work for some time. At the Lowmoor Furnaces in Virginia, just East of the White Sulphur Springs, W. Va., the blast furnaces, numbering two, were supplied with coke ovens located at the plant, and one of the sights passing along on the Chesapeake & Ohio Ry. was the gases burning over the beehive ovens. Practically all of these old stacks have been abandoned now, but it was about the most pleasant experiences in chemistry that one could have had to have worked at these old plants, my own experience dated from 1899 at Bristol furnace, Bristol, Va.-Tenn.; then the Radford furnace 1900, at Radford, Va.; Buena Vista furnace 1901-1902; Crozer furnaces, Roanoke, Va., 1901-1902; Supt. of the Buena Vista furnace 1902; Supt. of the Goshen furnace 1903; Bon Air Coal & Iron Co., Tenn., 1904; Chemist for Embreeville Iron Co., Embreeville, East Tenn., 1904-1905; then I took a long hop and landed at North Sydney, N. S., Canada, as chemist for the Nova Scotia Steel & Coal Co., Ltd., 1905-1908, then returned to the States, and have been chemist, Supply Dept., Norfolk Navy Yard to date.

My experience with old timers and blast furnace laboratories, was always extremely interesting and I was in a beautiful mountain country, and enjoyed the work and the associations one makes at iron plants. There was a certain amount of freemasonry among iron masters, that is not to be found in any other metallurgical profession. The prospecting for ores, the sampling of ore trains, general laboratory work, contributions to the American Chemical Society, Engineering & Mining Journals, of different phases of metallurgical work, coal washing, and coking of coals in by-product ovens. I still have iron and steel work under my charge as this yard operates a large steel and cast iron foundry, so that I have been constantly in this branch of chemistry for the past 33 years. I enclose my photograph which was taken in our laboratory last year, showing me amidst chemical apparatus.

The old days in the iron and steel business were the most happy of my life, at those isolated mountain plants. We had none of the modern electric heating devices, and the only text books were Blairs' Chemical Analysis of Iron, Stillmans Engineering Chemistry, and a small Chemical & Metallurgical hand book by Cremer & Bickwell, Cleveland, Fresenius, and a copy of Dana completed the technical library.

Editor, METALS & ALLOYS:

I was very much interested in the article on Early Blast Furnaces in the March number of Metals and Alloys.

I quote below from data I had gotten together with reference to the early industry in Mifflin and adjoining counties. Burnham is located in Mifflin County. I thought you would be particularly interested in the items and figures given covering the cost of pig iron in 1831:

In 1850 John A. Wright described the Iron Industry of Mifflin, Huntingdon, and Centre making "Juniata" iron as a very important district. Twelve ranges of mountains furnish vast bodies of woodland unfit for cultivation and the wood made strong charcoal. Huntingdon County supplied Pittsburgh, the others depended on the Philadelphia markets. The iron was, and is, equal to the best Swedish or Russian. The stock of these charcoal furnaces was in preparation 20 months before it was used, the year's stock being worth $25,000 to $35,000.

The average number of men employed at a furnace making 1,000 tons a year was not less than 70, and of horses 50. The proprietor's store sold goods to the value of about $8,000. The furnace cost $20,000, required 7,000 acres of woodland counted at $1 per acre, $10,000 was invested in teams and outfit, and $20,000 working capital was needed for the business of one furnace; a total of $57,000.

The average cost of pig iron in the three counties was then $20, exclusive of interest, and it then sold in Philadelphia at $25 per ton—that is, at a loss, for the average freight was $5.25 and expenses $2.25, making $27.50. The competition of anthracite and coke iron had already begun to tell, and unusual quantities of British iron were sold at any price.

In 1831 Hardman Phillips and George Valentine found, in the counties of Centre and Huntingdon, the following consumption of produce per ton of bar iron and castings made:

20 bushels wheat and rye, average 75c	$15.00
57 pounds pork, average 5 cents	2.85
43 pounds beef, average 4 cents	1.72
10 pounds butter, average 12½ cents	1.25
2 bushels potatoes, average 30 cents	.60
½ ton hay, average $7	3.50
For every 10 tons bar iron one horse is employed one whole year, worth $100, and one horse dies per annum out of every seven so employed, causing a charge of	$ 1.43
For fruits and vegetables	1.00
	$27.35

These figures were derived from actual returns, and at that time these counties were "the most extensively engaged in the manufacture of iron in Pennsylvania."

April 8, 1933 — A. A. STEVENSON

Ardmore, Pa.

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The Nature of the Solid Solution of Aluminum in Silver

(Continued from Page 64)

Comparison of Measured and Calculated Densities

The densities as calculated from these parameter measurements on the basis of the simple substitutional theory are listed in the next to last column of Table II and are plotted in Fig. 3. Included in Fig. 3 is also the density calculated for a 19 atomic % alloy studied by Westgren and Bradley,[5] and the densities calculated on the simple substitutional theory by Phelps and Davey from their parameter measurements. Two sets of measured densities are available and are plotted in Fig. 3; those of the present investigation, listed in Table I, and those of Phelps and Davey.

The close agreement between the calculated and observed densities confirms the simple substitutional theory. There remains no evidence for an abnormal type of solid solution nor by inference for the existence of molecules in the solid solution.

Summary

1. The solid solution of aluminum in silver decreases the lattice parameter linearly at the rate of 0.0012 A.U. per atomic % of aluminum.

2. The solid solution of aluminum in silver decreases the density linearly at the rate of 0.069 per atomic % of aluminum.

3. Contrary to previously published results, a comparison of calculated and observed densities shows this solid solution to be simple substitutional in type.

It is a pleasure to acknowledge the kindness of Mr. H. V. Churchill of the Aluminum Company of America in furnishing the analyses of the alloys.

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[5] A. Westgren & A. J. Bradley. *Philosophical Magazine*, Vol. 6, 1928, page 280.

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Coolidge Sherman has recently been appointed Assistant General Sales Manager of the Ludlum Steel Company, Watervliet, N. Y. Mr. Sherman has held various positions in the Ludlum sales organization since his graduation from Yale in 1916, including his recent post of Assistant to the President. He has devoted the major portion of his time to the promotion of the Ludlum stainless steels and heat resisting alloys. He will continue to be located at the executive offices of the Company at Watervliet.

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Earl C. Smith, Chief Metallurgical Engineer of Republic Steel Corp., Youngstown, Ohio, addressed a meeting of the American Society for Steel Treating at Muncie, Ind., March 1, on "Alloy Steels from the Manufacturer's Viewpoint." Mr. Smith's talk was a correlation of the factors affecting the manufacture, treatment, and applications of alloy steels of accepted and widely used analyses.

Mr. Smith has been selected to address the Iron & Steel Institute, May 19, 1933, on "Stainless Steel Production." A graduate of Ohio State University, he was later connected with the Gary works of the U. S. Steel Corp. After this he returned to Ohio State University as an instructor. During the war he was associated with the U. S. Aircraft Production Office at Pittsburgh, going to the Republic Steel Corp. in 1919.

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The Electro-Alloys Company, Elyria, Ohio, has retained as consultants the Victoreen Instrument Company of Cleveland, specialists in the field of X-ray radiography and is prepared to furnish radiographs of their Thermalloy equipment at only a slight additional cost.